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American Fisheries Society

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THE AMERICAN FISHERIES SOCIETY

Organized 1870 Incorporated 1910

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

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Seth Gordon ..... Harrisburg, Pa.
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Henry B. Ward ..... Urbana, Ill.

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W.Va.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36. E. A. Birge	1906-1907	Grand Rapids, Mich.
37. Hugh M. Smith	1907-1908	Erie, Pa.
38. Tarleton H. Bean	1908-1909	Washington, D. C.
39. Seymour Bower	1909-1910	Toledo, Ohio
40. William E. Meehan	1910-1911	New York, N. Y.
41. S. F. Fullerton	1911-1912	St. Louis, Mo.
42. Charles H. Townsend	1912-1913	Denver, Colo.
43. Henry B. Ward	1913-1914	Boston, Mass.
44. Daniel B. Fearing	1914-1915	Washington, D. C.
45. Jacob Reighard	1915-1916	San Francisco, Calif.
46. George W. Field	1916-1917	New Orleans, La.
47. Henry O'Malley	1917-1918	St. Paul, Minn.
48. M. L. Alexander	1918-1919	New York, N. Y.
49. Carlos Avery	1919-1920	Louisville, Ky.
50. Nathan R. Buller	1920-1921	Ottawa, Canada
51. William E. Barber	1921-1922	Allentown, Pa.
52. Glen C. Leach	1922-1923	Madison, Wis.
53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, Canada
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Arkansas
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, Canada
65. Frank T. Bell	1935-1936	Tulsa, Oklahoma
66. A. G. Hunstman	1936-1937	Mexico City, Rep. of Mex.

TABLE OF CONTENTS

	Page
List of Officers	3
Committees, 1936-1937	4
Past Presidents	6

PART I. BUSINESS SESSIONS

Registered Attendance	15
Report of the Secretary-Treasurer, *Seth Gordon*	18
Report of Librarian, *Eben W. Cobb*	21
Minutes of Meeting of Executive Committee, *Seth Gordon*	23
Report of the Committee on Foreign Relations, *W. F. Thompson*	24
Report of the Committee on Common and Scientific Names of Fishes, *Carl L. Hubbs*	28
Report of Committee on American Fish Policy, *E. L. Wickliff*	29
Report of Pollution Study Committee, *Talbott Denmead*	29
Report of the Division of Fish Culture, *T. H. Langlois*	32
Report of the Division of Aquatic Biology and Physics, *A. S. Hazzard*	34
Report of the Division of Commercial Fishing, *R. H. Fiedler*	34
Report of the Division of Angling, *S. B. Locke*	37
Appointment of Committees	38
Report of Auditing Committee	40
Report of Committee on Resolutions	40
Report of Special Committee on Revision of By-Laws	42
Report of Committee on Time and Place	43
Report of Committee on Nominations	43
In Memoriam	48

PART II. PAPERS AND DISCUSSIONS

Fish Management: Looking Forward, *Carl L. Hubbs*	51
Observations on Natural Versus Artificial Propagation of Commercial Species of Fish in the Great Lakes Region, *Lester Smith*	56
Some Fishery Problems in Impounded Waters, *M. M. Ellis*	63

Page

Some Studies of Impounded Waters in Ohio, *E. L. Wickliff* and *Lee S. Roach* 76

A Comparison of Summer and Winter Fishing in Michigan Lakes, *A. S. Hazzard* and *R. W. Eschmeyer* 87

Fish Movement Under the Ice in An Iowa Lake, *W. W. Aitken* 98

Some Observations on Minnesota Fish Ponds, *Thaddeus Surber* and *Theodore A. Olson* 104

Michigan Lake Survey—A Cooperative Enterprise, *Donald E. Miller* 128

The Great Lakes Fisheries: Their Proper Management for Sustained Yields, *John Van Oosten* 131

The Biological and Economic Importance of the Smelt in Green Bay, *Edward Schneberger* 139

The Increase in the Abundance of the Yellow Pike-Perch, *Stizostedion Vitreum* (Mitchill), in Lakes Huron and Michigan, in Relation to the Artificial Propagation of the Species, *Ralph Hile* 143

The Dispersal of Smelt, Osmerus Mordax (Mitchill), in the Great Lakes Region, *John Van Oosten* 160

The Spread of the Sea Lamprey Through the Great Lakes, *Carl L. Hubbs* 172

Experimental Evidence on the Value of Trout Stream Improvement in Michigan, *Clarence M. Tarzwell* 177

Some Principles of Biological Fisheries Research, *Leonard P. Schultz* 188

Rainbow Trout and Bottom Fauna Production in One Mile of Stream, *Eugene W. Surber* 193

Migration, Growth Rate, and Population Density of Brook Trout in the North Branch of the Au Sable River, Michigan, *David S. Shetter* 203

Atlantic Salmon Parr of the West Coast Rivers of Newfoundland, *David L. Belding* 211

Striped Bass Investigations in the Chesapeake Bay, *R. V. Truitt* and *V. D. Vladykov* 225

The Date of Annual Ring Formation in the Scales of the White Crappie, *Donald F. Hansen* 227

The Submarine Physiography and Oceangraphical Problems of the Scotian Shelf, *H. B. Hachey* 237

Food Habits, Rate of Growth and Cannibalism of Young Largemouth Bass (*Aplites Salmoides*) in State-Operated Rearing Ponds in Michigan During 1935, *Gerald P. Cooper* 242

Foes Encountered in the Rearing of Smallmouth Bass, *Oliver R. Kingsbury* 267

Further Observations on Habits of the Crayfish, *Cambarus Rusticus* Girard, *T. H. Langlois* 275

Page

Artificial Propagation of Walleyed Pike, *George E. Butler* 277

Hatching Fry in Gravel No. 2, *Alexander Robertson* 279

Report on the Effect of Gravel in Raceways, *James Savage* 283

Notes on the Food of *Daphnia Pulex* (De Geer) in Fertilized Water, *M. W. Smith* 287

Identification of Factor "H" in the Nutrition of Trout, *Edward R. Hewitt* 291

Why is there No Text Book on Fish Culture? *J. E. Bost* 298

How California is Measuring the Angler's Catch, *Richard S. Croker* 301

A Fish Yield Study for Certain Lakes in the Chequamegon National Forest, *Winston A. Elkins* 306

A Creel Census from Dry River, New Hampshire, *Osgood R. Smith* 313

Tagging Native Stream Fish, *R. V. Bangham* 316

A Second Season of Creel Census on Fife Lake, *R. W. Eschmeyer* 324

Studies on Merganser Depredations in Michigan Trout Waters, *J. W. Leonard* and *David S. Shetter* 335

The Destruction of Trout by Fish Ducks, *U. Sidney Beach* 338

Observations on the Parasites of the Speckled Trout in Lake Edward, Quebec, *L. R. Richardson* 343

Parasites of Wayne County (Ohio) Stream Fish, *R. V. Bangham* 357

An Air Bladder Disease in Lake Trout Fingerlings, *Louis E. Wolf* 359

Bass Tapeworm Infection in a Rearing Pond, *T. H. Langlois* 364

The Introduced Largemouth Bass, A Predator Upon Native Cuban Fishes, *Luis Howell Rivero* 367

Blood Clots in the Gills of Trout, *Louis E. Wolf* 369

Breeding and Food Habits of the Pikes, *(Esox Lucius and Esox Vermiculatus), Fred McNamara* 372

The Food of Sculpins (Cottidae) in Central New York, *Wm. J. Koster* .. 374

Fresh Water Fishery Problems of the British Isles, *W. Rushton* 383

Fish Increase Responds to Government and State Cooperation, *Swepson Earle* 392

Protection of Native Fishes in the National Parks, *David H. Madsen* 395

The Fisheries Program in the Tennessee Valley, *Alvin R. Cahn* 398

The Importance of Sport Fishing in Maryland, *R. V. Truitt* and *V. D. Vladykov* 403

The Relationship of the Gravid Periods of Certain Mussels in Michigan to the Pearl Button Industry, *Henry van der Schalie* 406

Page

The Warner-Bower Fish Conveyor, *E. A. Bower* 411

Composition and Utilization of the Atlantic Whiting, *Merluccius Bilinearis*, *D. A. Bean, J. A. Clague* and *C. R. Fellers* 415

Sampling Errors in Calculating the Weight of Fish in Ponds, *C. McC. Mottley* 422

The Factory Ship—Its Significance to Our World Trade and Commerce, *R. H. Fiedler* 427

APPENDIX

Certificate of Incorporation 445

Constitution and By-Laws 446

List of Members 450

Suggestions for Preparing and Editing Manuscripts for the Transactions of the American Fisheries Society 468

Index 471

PART I
BUSINESS SESSIONS

TRANSACTIONS

of the 66th Annual Meeting of the

AMERICAN FISHERIES SOCIETY

GRAND RAPIDS, MICHIGAN

September 2, 3 and 4, 1936

FRANK T. BELL, *Presiding*

The 66th Annual Meeting of the American Fisheries Society convened at 9:30 A. M., on September 3, 1936 at the Hotel Pantlind, Grand Rapids, Michigan, the President, Frank T. Bell of Washington, D. C., presiding.

The meetings were held in cooperation with the International Association of Game, Fish and Conservation Commissioners.

The registered attendance of members, delegates, and guests was as follows:

REGISTERED MEMBERS IN ATTENDANCE

Adams, Harry, Milwaukee, Wisconsin
Adams, Milton P., Lansing, Mich.
Aitken, W. W., Des Moines, Iowa
Aldrich, A. D., Tulsa, Okla.
Allen, W. R., Lexington, Ky.
Atwood, Earl, St. Louis, Missouri

Baird, John C., Springfield, Mo.
Baker, C. L., Memphis, Tenn.
Balch, Howard K., Milwaukee, Wis.
Bangham, R. V., Wooster, Ohio
Beach, U. Sidney, Highland, Mich.
Belding, David L., Hingham, Mass.
Bell, Frank T., Washington, D. C.
Bennington, N. L., Wooster, Ohio
Bost, J. E., Greer, South Carolina
Bower, E. A., Benton Harbor, Mich.
Bradt, G. W., Lansing, Mich.
Brass, John, Hastings, Mich.

Cahalane, Victor H., Washington, D. C.
Cahn, A. R., Knoxville, Tenn.
Carbine, Wm. Fenton, Ann Arbor, Mich.
Chalk, J. D., Raleigh, North Carolina
Chute, Walter H., Chicago, Ill.
Clark, Arthur L., Hartford, Conn.
Clark, O. H., Ann Arbor, Mich.
Cobb, Eben W., Unionville, Mich.
Cobb, Kenneth A., Windsor Locks, Conn.
Cook, A. B., Jr., Ionia, Mich.
Cooper, Gerald P., Ann Arbor, Mich.
Culler, C. F., LaCrosse, Wis.

Davis, Henry P., Washington, D. C.
Davis, Herbert C., Sacramento, Calif.
Davis, H. S., Washington, D. C.
Deason, H. J., Ann Arbor, Mich.
DeBoer, M. J., Lansing, Mich.
Denmead, Talbott, Washington, D. C.

Earle, Swepson, Washington, D. C.
Elkins, Winston, Bark Falls, Wis.
Ellis, M. M., Columbia, Mo.
English, P. F., Storrs, Conn.
Eschmeyer, R. W., Ann Arbor, Mich.

Fiedler, R. H., Washington, D. C.
Follett, Richard E., Detroit, Mich.
Foresman, Bud, Pontiac, Mich.
Fortney, Robert, Paris, Mich.
Friedrich, George W., St. Cloud and St. Paul, Minn.

Garrett, C. Clyde, San Francisco, Calif.
Gillingham, Weston, Bay Port, Mich.
Gordon, Seth, Harrisburg, Pa.
Gray, Donald, East Tawas
Greeley, John R., Albany, N. Y.
Greene, C. W., Albany, N. Y.
Grim, D. N., Gleneyre, Penna.

Hansen, Donald F., Urbana, Ill.
Hanson, A. C., St. Paul, Minn.
Harkness, W. J. K., Toronto, Ontario, Canada
Haskell, David, Gansevoort, N. Y.
Hayford, Robert A., Hackettstown, N. J.
Hazzard, A. S., Ann Arbor, Mich.
Heiliger, Dudley B., Northville, Mich.
Hewitt, Edw. R., New York, N. Y.
Higgins, Elmer, Washington, D. C.
Hildebrand, Samuel F., Washington, D. C.
Hile, Ralph, Ann Arbor, Mich.

Hill, R. R., Milwaukee, Wis.
Hoffmaster, P. J., Lansing, Mich.
Hogan, Joseph, Lonoke, Ark.
Hoover, Earl E., Concord. New Hampshire
Hubbs, Carl L., Ann Arbor, Mich.
Hunter, R. P. Montpelier, Vt.
Huntsman, A. G., Toronto, Ontario, Canada

James, H. D., Summerville, Georgia
James, M. C., Washington, D. C.
Johnson, Jimmie, Sante Fe, New Mexico

Kingsbury, O. R., South Otceiling, N. Y.
Kunkel, K. M., Indianapolis, Ind.
Kuronuma, Katsuzo, Ann Arbor, Mich.

Langford, R. R., Toronto, Ontario, Canada
Langlois, T. H., Columbus, Ohio
LeCompte, E. Lee, Baltimore, Md.
Leonard, J. W., Ann Arbor, Mich.
Lincoln, Guy, Oden, Mich.
Locke, S. B., Chicago, Ill.
Loutit, W. H., Grand Haven, Mich.
Lydell, Claude, Comstock Park, Mich.

McNamara, Fred, Howell, Mich.
MacKay, H. H., Toronto, Ontario, Canada
Mackenzie, H. W., Madison, Wis.
Marks, J. G., Mattawan, Mich.
Marks, Ralph S., Watersameet, Mich.
Markus, Henry C., Rochester, N. Y.
Miller, Donald E., Ann Arbor, Mich.
Morofsky, W. F., East Lansing, Mich.

Newcomb, W. E., Cleveland, Ohio

O'Connell, Frank B., Lincoln, Nebr.
Olson, Herman, Duluth, Minn.
Osburn, Raymond C., Columbus, Ohio
Osgood, Wayland, Lansing, Mich.

Palmer, George, Louistown, Md.
Peterson, Hans L. Grayling, Mich.
Pirnie, M. D., Battle Creek, Mich.
Potts, Lloyd W., Harrisville, Mich.
Powell, A. M., Baltimore, Md.
Purdy, N. H., Urichsville, Ohio

Quinn, I. T., Montgomery, Ala.

Regan, C. C., Covington, Ky.
Reid, Kenneth A., Connellsville, Penna.
Richards, W. F., Mason, Mich.
Rivero, Luis Howell, Cambridge, Mass. (Havana, Cuba)
Roach, Lee S., Columbus, Ohio
Rodd, J. A., Ottawa, Ontario, Canada
Rodeheffer, I. A., Ann Arbor, Mich.

Sauheitel, Louis, Marquette, Mich.
Schneberger, Edw., Sturgeon Bay, Wis.
Schultz, Leonard P., Seattle, Wash.
Shawhan, H. W., Charleston, West Va.
Shetter, David S., Ann Arbor, Mich.
Shoemaker, Carl D., Washington, D. C.
Shust, Stanley, Manistique, Mich.
Smith, Lester, Port Washington, Wis.
Speaker, Everett, Des Moines, Iowa
Stewart, A. T., Drayton Plains, Mich.
Stobie, Robert H., Concord, N. H.
Surber, T., St. Paul, Minn.

Thompson, C. F., Springfield, Ill.
Thompson, David H., Urbana, Ill.
Thompson, H. L., Benton Harbor, Mich.
Thompson, W. F., Seattle, Wash.
Thorpe, Lyle M., Hartford, Conn.
Trautman, Milton B., Ann Arbor, Mich.
Trippensee, R. B., Amherst, Mass.
Tucker, William J., Austin, Texas
Tunison, A. V., Cortland, N. Y.

van der Schalie, Henry, Ann Arbor, Mich.
Van Oosten, John, Ann Arbor, Mich.
Ver Duin, Claude, Grand Haven, Mich.
Vladykov, V. D., Solomons Island, Md.
Von Ihering, Rodolpho, Fortaleza, Ceara, Brazil, South America

Webster, B. O. Madison, Wis.
Westerman, Fred A., Lansing, Mich.
Westfall, B. A., Columbia, Mo.
Wickliff, E. L., Columbus, Ohio
Widmeyer, E. R., Northville, Mich.
Wilkinson, James T., East Lansing, Mich.
Wolf, Louis E., Ann Arbor, Mich.
Woodbury, Lowell, Ann Arbor, Mich.
Wright, Stillman, Fortaleza, Brazil, South America
Zinser, Juan, Mexico City, Mexico

Registered Visitors in Attendance

Adams, L. A., Urbana, Ill.
Adams, Mrs. Milton P., Lansing, Mich.
Aitken, Mrs. W. W., Des Moines, Iowa
Amadon, Dean, Hartford, Conn.
Antles, I. A., Grand Haven, Mich.
Arnold, Lloyd, Louistown, Md
Atwood. Mrs. Earl. St. Louis. Mo.

Bagdon, Vincent, Grand Rapids, Mich.
Barley, Mrs. Gertrude, Lansing, Mich.
Bartlett, I. H., East Lansing, Mich.
Baumgartner, F. M., Lansing, Mich.
Baxter, William, Wilmington, Dela.
Bazuin, C. W., Grand Rapids, Mich.
Beaudette, Bert, Benton Harbor, Mich.
Belding, Mrs. David L., Hingham, Mass.
Belding, Ellinor F., Hingham, Mass.
Belding, Helen W., Hingham, Mass.
Bergin, W. A., Lansing, Mich.
Bogue, Arthur P., Pontiac, Mich.
Bogue, Barney, Pontiac, Mich.
Bowman, C. W., East Jordan, Mich.

Bradley, Homer, Augusta, Mich
Brevitz, R. F., Lansing, Mich.
Bugai, Joseph F., East Jordon, Mich.

Canfield, H. L., LaCrosse, Wis.
Cheatum, E. L., Ann Arbor, Mich.
Chute, Mrs Walter H., Chicago, Ill.
Coburn, Don R., East Lansing, Mich.
Collis, Vic, Benton Harbor, Mich.
Creech, Stephen, Bay City, Mich.
Creswell, Harry L., Grand Rapids, Mich.

Davenport, L. A., Lansing Mich.
DeBlaay, John, Grand Rapids, Mich.
Denner, Frank, Kalamazoo, Mich.
Doremus, T. E., Wilmington, Dela.
Dornbos, Lawrence, Grand Haven, Mich.
Dow, C. E., Benton Harbor, Mich.
DuMond Frank L. Grand Rapids, Mich.

Earle, Mrs. Swepson, Washington, D. C.
Early, Walter T., Ironwood, Mich.

East, Ben, Grand Rapids, Mich.
East, Mrs. Ben, Grand Rapids, Mich.
Egbert, George, Lansing, Mich.
Elwood, P. H., Ames, Iowa

Fearnow, Theodore C., Berkley Springs, West Virginia
Foresman, Robt., Pontiac, Mich .
Frispie, George C., Escanaba, Mich.
Fry, V. E. J., Tronoto, Ontario, Canada

Gabrielson, Ira N., Washington, D. C.
Gerlach, C. S., Kalamazoo, Mich.
Gerred, M. S., Gaylord, Mich.
Gill, G. H., Ames, Iowa
Gillespie, R. J., Lansing, Mich.
Gillett, F. C., East Lansing, Mich.
Gordon, Myron, Ithaca, N. Y.
Gordon, Phyllis, Harrisburg, Penna.
Gordon, Mrs. Seth, Harrisburg, Penna.
Greess, Frank N., Sturgeon Bay, Wis.
Gutermuth, C. R., Indianapolis, Ind.
Gutermuth, Mrs. C. R., Indianapolis, Ind.

Hall, Otto H., Gaylord, Mich.
Hammar, Karl J., Escanaba, Mich.
Hansen, E. E., Grand Rapids, Mich.
Headden, Damon, Nashville, Tenn.
Herbert, P. A., East Lansing, Mich.
Hickie, Paul, Lansing, Mich.
Hicks, Lawrence E., Columbus, Ohio
Hogan, Mrs. Joseph, Lonoke, Ark.
Hogan, W. Murray, Nashville, Tenn.
Holland, Ancil, Cleveland, Tenn.
Hopkins, William, Muskegon, Mich.
Hubbs, Mrs. Carl L., Ann Arbor, Mich.

James, Emerson W., Port Henry, N. Y.
James, Mrs. Emerson W., Port Henry, N. Y.
Janes, E. G., New York, N. Y.
Janzen, Daniel, Lansing, Mich.
Jenkins, Ben, Lansing, Mich.
Jordan, Robert, Lansing, Mich.
Justin, C. A., Grand Rapids, Mich.

Kellogg, Henry L., Chicago, Ill.
Kingscott, W. J., Lansing, Mich.
Kroll, J. A., Grand Rapids, Mich.
Kuizema, Dorr, Grand Rapids, Mich.

Lamoreaux, J. E., Comstock Park, Mich.
Lamoreaux, Roy V., Jackson, Mich.
Langlois, Mrs. T. H., Columbus, Ohio
Loutit, Mrs. W. H., Grand Haven, Mich.
Lovejoy, P. S., Ann Arbor, Mich.
Lydell, Frank, Comstock Park, Mich.
Lydell, Mrs. Jennie, Lansing, Mich.

McCall, H. G., Little Rock, Ark.
McIntire, George S., Lansing, Mich.
MacDonald, W., Grand Rapids, Mich.
Mack, Keith H., Lewiston, Mich.
Marble, George, Pontiac, Mich.
Marsh, V. G., Grand Rapids, Mich.
Marshall, Robert, Washington, D. C.
Marzolf, Allan L., Grand Rapids, Mich.
Meigs, Mrs. Laura, Seattle, Wash.
Meigs, Robert, Seattle, Wash.
Miller, A. F., Muskegon, Mich.
Mooding, Ervin, Kalamazoo, Mich.
Munger, John L., Benton Harbor, Mich.
Murphy, Warren T., East Tawas, Mich.

Newman, Miss Anne, Chicago, Ill.
Nichols, J. T., New York, N. Y.

O'Brien, Roy, Allegan, Mich.
O'Roke, E. C., Ann Arbor, Mich.
Ottenhoff, Herman, Shingleton, Mich.

Perry, Jerrard, Lansing, Mich.
Peters, Mrs. Mildred, Lansing, Mich.
Peterson, Floyd, Grand Rapids, Mich.
Purdy, Mrs. N. H., Uhrichsville, Ohio
Pyle, C. M., Grand Rapids, Mich.

Rahilly, Larry, Michigamme, Mich.
Regan, Mrs. C. C., Covington, Ky.
Roberts, Charles A., Kent City, Mich.
Roberts, Elsie M., Kent City, Mich.
Robson, D., Lansing, Mich.
Rodd, Mrs. J. A., Ottawa, Ontario, Canada
Rodeheffer, Mrs. I. A., Ann Arbor, Mich.
Rogers, John I., Lansing, Mich.
Rudolphi, Annette, Ann Arbor, Mich.
Rushton, John C., London, England
Rushton, Wilfred, London, England

Sanderson, William M., East Jordan, Mich.
Schneberger, Mrs. Edw., Sturgeon Bay, Wis.
Schultz, Mrs. Leonard P., Seattle, Wash.
Shantz, H. L., Washington, D. C.
Shawhan, Mrs. H. W., Charleston, W. Va.
Shetter, Mrs. David S., Ann Arbor, Mich.
Smith, Mrs. Lester, Port Washington, Wis.
Smith, R. A., Lansing, Mich.
Smith, Mrs. R. A., Lansing, Mich.
Speck, John, Oxford, Mich.
Sproat, Earl L., Grand Rapids, Mich.
Stebler, Adolph M., Lansing, Mich.
Stephenson, J. H., Boyne Falls, Mich.
Stevens, Fred F., Oxford, Mich.
Stoll, Albert, Jr., Detroit, Mich.
Stoudt, Jerome, Cass Lake, Minnesota
Stoye, F. H., New York, New York
Switzenberg, D. F., Allegan, Mich.

Tawse, James I., Jackson, Mich.
Titus, Harold, Traverse City, Mich.
Tubbs, F. F., Lansing, Mich.

Van Coevering, Jack, Detroit, Mich.
Vanderwall, E. J., Madison, Wisconsin
Van Norman, John, Manistee, Mich.
Van Oosten, Mrs. John, Ann Arbor, Mich.
Vaughan, Coleman, Rhinelander, Wisconsin

Wakeman, Max, Lansing, Mich.
Walcott, A. J., Harrietta, Mich.
Ward, Miss Dorothy, Ann Arbor, Mich.
Webb, Martin R., Lansing, Mich.
Webster, Mrs. B. O., Madison, Wisconsin
Westerman, Mrs. Fred A., Lansing, Mich.
White, Flossie, Washington, D. C.
White, J. M., Montgomery, Alabama
Whitlock, S. C., Lansing, Mich.
Whitworth, J. A., Grand Rapids, Mich.
Wickliff, Mrs. E. L., Columbus, Ohio
Wolf, Mrs. Louis E., Ann Arbor, Mich.
Woodford, Miss Leah, Ann Arbor, Mich.

Young, Earl C., Ottawa, Ontario, Canada
Young, Mrs. Earl C., Ottawa, Ontario, Canada
Young, George A., Lansing, Mich.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

For the Year 1935-1936

SETH GORDON

During the fiscal year 1935-1936 the Society added to its membership 104 active members, seven clubs and dealers, one library and eleven state members, a total of 123 new members. Comparing these figures with the statistics for the year 1934-1935, there has been a gain of six members. I am particularly pleased to report that more states have realized the value of holding a membership in the Society but there are still many states and provinces that should be affiliated with the organization. I hope by the close of the next fiscal year the Secretary may report an even greater number of state and provincial affiliations.

While we showed a gain in new members over the previous year yet our losses were considerably heavier. Due to the revision in our Constitution and By-Laws we were compelled to drop for non-payment of dues seventy-three former active members, three clubs and dealers and one state, a total of seventy-seven members, twenty-six more than for the previous fiscal year. For this period we had eleven resignations comprising ten active members and one state. Death, according to information received, took a toll of nine of our members. Our losses for the entire year were ninety-seven members, showing a gain of twenty-eight members, just one less than for the fiscal year 1934-1935.

While the past few years have shown an increase in the membership, yet there are hundreds and hundreds of men engaged in the field of fish culture, co-workers of our members, who should be affiliated with this Society. These are the men we want on our roster. It is the duty of each and every member to go out and sell the Society to these persons. Many of our members have put their shoulder to the wheel but there are a whole lot who are willing to sit back and let the other fellow do it. As an example of what can be done, one of our members (Fred J. Foster) secured 18 new members during the past year. Let's all pull together and make 1936-1937 a banner year.

In summarizing our losses for the year I mentioned that death had taken nine of our members. The Society suffered a great loss in the passing of Henry O'Malley on April 24, 1936. A very active member since 1900, Mr. O'Malley did much to promote the work of the Society, serving as its president for 1917-1918. He served as Commissioner of U. S. Bureau of Fisheries from May 13, 1922 to April 15, 1933.

At the close of the previous fiscal year our outstanding indebtedness amounted to $525.00. The outstanding obligations at the close of the fiscal year, June 30, 1936 amounts to $506.79 which is composed of $150.00, balance due on bill for printing 1935 Transactions, and $356.79 for printing separates. The latter amount will be refunded by those ordering reprints. Five hundred dollars were transferred from the Permanent Fund to the General Fund during the previous fiscal year to help defray some of the unusual expenses. From the foregoing you will note our treasury is in somewhat better condition than at the time of my last report, but the Society should either enlarge its membership or increase the dues slightly to provide enough income to cover all obligations at the end of each fiscal year.

TREASURER'S REPORT

July 1, 1935 to June 30, 1936

General Fund

Receipts		
Balance on hand July 1, 1935		$ 28.74
Annual Dues:		
Individuals and Libraries		
For the year 1932-1933	$ 18.00	
1933-1934	47.00	
1934-1935	115.00	
1935-1936	1,226.94	
1936-1937	515.00	1,921.94
Clubs and Dealers		
For the year 1934-1935	5.00	
1935-1936	110.00	
1936-1937	70.00	185.00
State Members		
For the year 1935-1936	280.00	
1936-1937	140.00	420.00
Sale of Transactions		304.40
Sale of Index		10.00
Sale of Separates		
1933 Transactions	.50	
1934 Transactions	479.86	
1935 Transactions	27.50	507.86
Exchange on checks		.87
Refund—membership fee		2.00
Total Receipts		$3,380.81
Disbursements		
Transactions		
1934, vol. 64		
Balance on printing		$ 525.00
1935, vol. 65		
Printing	$1,611.84	
Reporting	100.00	
Proofreading	50.00	
Indexing	106.68	1,868.52
Postage		87.25
Rental Safe Deposit Box		5.50
Office supplies		10.47
Stationery and printing		58.77
Express		6.17
Clerical and secretarial expense		
Ethel M. Quee	150.00	
Seth Gordon	100.00	250.00
Traveling and entertaining		4.95
Miscellaneous		1.85

Refund		
1934 Separates	2.76	
Membership dues	4.60	7.36
Purchase of Transactions		5.50
Exchange on checks		6.22
Telegraph		3.20
Premium on bond		18.75
Separates, 1934		449.00
Returned check		13.04
Total Disbursements		$3,321.25
Receipts General Fund	$3,380.81	
Disbursements General Fund	3,321.25	
Balance on hand July 1, 1936		*$ 59.56
*Outstanding obligations		
Total outstanding obligations, June 30, 1936		$ 506.79
A year ago this amounted to		525.00

PERMANENT FUND

RECEIPTS		
Balance on hand July, 1935		$ 140.98
Interest on savings account	$ 6.55	
Interest on mortgage certificates	200.87	
Dividends on Commonwealth Southern pfd.	30.00	237.42
Total Receipts		$ 378.40
DISBURSEMENTS		
None		
Balance on hand July 1, 1936		$ 378.40
Par value of certificates		$5,000.00
Par value 10 shares Commonwealth Southern pfd. @ $100 each		1,000.00
Total		*$6,000.00

*The market value of certificates during the past year has been far below par, but since there is no open market no established cash value is available. The cash value of the 10 shares of Commonwealth Southern Preferred, par value $100, as of June 30, 1936 was $701.25.

For the further information of the members of the Society, during the period of July 1 to August 26, we had receipts of $765.98 and expended $106.20, having a balance on hand in the General Fund of $719.34 as of August 26. During this same period we received 26 individual applications for membership.

Outstanding obligations on August 26, 1936 were:

Monumental Printing Co.		
Balance due on printing 1935 Transactions	$ 150.00	
Separates	356.79	
Express and freight charges	3.57	
Invitations (final notice)	6.25	$ 516.61

Fred H. Williams & Co.

Additional on premium (fire insurance)	1.13
Total outstanding obligations	$ 517.74

The report of the Secretary-Treasurer was received and referred to the Auditing Committee, and later upon approval of the committee was accepted as submitted.

REPORT OF LIBRARIAN

EBEN W. COBB

All volumes of the Society's Transactions are kept in the vaults of the State Office Building, Hartford, Connecticut, where they are insured against loss.

Office or library copies on file at Hartford, August 1, 1936:

Year	*Number on hand*	*Year*	*Number on hand*
1876	1	1910	2
1884	1	1911	2
1885	2	1912	2
1886	2	1913	2
1887	1	1914	2
1888	2	1915	2
1889	2	1916	2
1890	2	1917	2
1891	2	1918	2
1892	2	1919	2
1893	2	1920	2
1894	2	1921	2
1895	2	1922	2
1896	2	1923	2
1897	2	1924	2
1898	2	1925	2
1899	2	1926	2
1900	2	1927	2
1901	2	1928	2
1902	2	1929	2
1903	2	1930	2
1904	2	1931	2
1905	2	1932	2
1906	2	1933	2
1907	2	1934	2
1908	2	1935	2
1909	2		

Additional copies of Transactions on hand, August 1, 1936, and available for sale:

Year	*Number on hand*	*Year*	*Number on hand*
1892	1	1916	5
1893	1	1917	60
1894	1	1918	34
1895	9	1919	149
1896	21	1920	121
1897	40	1921	77
1898	39	1922	68
1900	1	1923	69
1901	1	1924	184
1904	30	1925	279
1906	114	1926	187
1907	111	1927	182
1908	125	1928	163
1909	92	1929	193
1910	82	1930	178
1911	77	1931	223
1912	147	1932	179
1913	148	1933	133
1914	14	1934	135
1915	16	1935	139

Cloth bound index—645
Paper bound index—216

REPORTS OF STANDING COMMITTEES

MINUTES OF MEETING OF EXECUTIVE COMMITTEE

The Executive Committee of the American Fisheries Society, heretofore the Council of the Society, met at the Hotel Pantlind, Grand Rapids, Michigan, at 8:30 P. M. on September 1, 1936, the following being present: Frank T. Bell, Washington, D. C., President; A. G. Huntsman, Toronto, Canada, First Vice-President; I. T. Quinn, Montgomery, Alabama, Second Vice-President; Seth Gordon, Harrisburg, Pennsylvania, Secretary-Treasurer; Eben W. Cobb, Hartford, Connecticut, Librarian; T. H. Langlois, Columbus, Ohio, Vice-President, Division of Fish Culture; A. S. Hazzard, Ann Arbor, Michigan, Vice-President, Division of Aquatic Biology and Physics; R. H. Fiedler, Washington, D. C., Vice-President, Division of Commercial Fishing; Carl D. Shoemaker, Washington, D. C., Vice-President, Division of Protection and Legislation; and E. L. Wickliff, Columbus, Ohio, the President last year.

The Secretary informed the Committee concerning the work of the Society during the past year, and the status of the treasury. Upon motion made and approved, the Secretary-Treasurer was directed to transfer $250.00 of the accumulated income in the Permanent Fund to the General Fund to help defray obligations incurred in connection with the printing of the 1935 Transactions.

The wisdom of increasing the dues of the several classes of members in order that the Society may operate without using income from the Permanent Fund was discussed. Upon motion made and adopted, it was decided not to increase the dues of individual members but to recommend to the Society that the State and Provincial dues be increased from $10.00 per year to $20.00, with the understanding that each state or provincial member, upon payment of this increased fee, shall receive three copies of the printed Transactions instead of only one copy as in the past, said increase to become effective immediately upon adoption for all new members, and for present members at the beginning of the next fiscal year. (This recommendation was later adopted by the Society).

The Committee also recommended that members make a special effort during the coming year to increase the number of individual members, and especially the number of library members in order that the printed transactions may become available to more communities throughout North America.

The difficulties encountered in preparing the program for the Annual Meetings when titles are submitted only ten days in advance were discussed, and since the joint committee on Time and Place had already voted to hold the 1937 meeting in Mexico City the Committee, upon motion made and carried, agreed that for the next meeting titles of all papers must reach the Secretary at least thirty (30) days in advance of the opening session. It also was agreed that authors shall submit with the titles of their papers (not more than two from one author) a short synopsis, not exceeding one page of double-space typewritten material, setting forth the scope and purpose of the proposed paper and the conclusions reached, the papers themselves to begin with a similar summary.

The meeting adjourned at 11:30 P. M.

SETH GORDON, *Secretary*

REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

W. F. Thompson

International cooperation on the North American continent for the care of fisheries exploited jointly by the various nations has made steady progress, continuing that recorded in previous reports to your society. There still remains much to be done, as will be made clear in what follows. Cooperation on a broader scale, with nations elsewhere than on this continent, has become a reality for the first time in the very much desired convention regarding whaling.

This convention should be of great interest to our Society as a distinct forward step in attainment of cooperation in solution of the problems which have arisen as the result of world-wide expansion of marine fisheries. On May 1, 1936, an act by the 74th Congress of the United States was approved by the President, giving effect to this multilateral convention which had been concluded at Geneva in 1931 between various powers. This became effective in 1934 when ratification by Great Britain and Northern Ireland was deposited. The Convention had been signed on behalf of Canada in 1931 and has been in effect in Canada since 1933.

It does not go as far as might be desired by many interested in conservation in that it applies only to baleen or whalebone whales. It prohibits the taking or killing of any right whale or any calf, suckling whale, immature whale, or any female whale accompanied by suckling calf. The sizes of immature whales of the more important species are specified in the whaling treaty act, and the sizes of other species will be specified by regulations to be issued under the act. The fullest possible use must be made of each whale taken. Information must be furnished by the operators as to the date of taking each whale, the place of taking, species, sex, length, and other pertinent information of biological value. On the part of the United States, regulations issued by the Secretaries of Commerce and of the Treasury are effective when approved by the President.

Also of great interest, although not previously commented upon by this Committee, has been the growing cooperation between the North American Council on Fishery Investigations and the International Council for the Exploration of the Sea. Discussions of and cooperation in research problems and organization of statistical systems along parallel lines are extremely valuable, especially as concerns the two sides of the Atlantic. The attendance of the chairman of the North American Council at the meeting of the International Council in Paris, May, 1933, was, in the opinion of your Committee, a most fortunate event.

Although international relations across the Atlantic are most significent, it remains true that relations between the North American nations themselves are of dominant interest to us. Your Committee is glad to call attention to the establishment of a Fisheries Research Commission in Newfoundland and the cordial relations it has as a member of the North American Council, which now includes representatives of the United States, Canada, France, and Newfoundland.

The relationships between Canada and the United States are of very great interest to this Society, as it includes a great many members from both countries. The Society typifies the close relationship and community of interest which the two have.

The two countries share fishery resources along a long boundary. It has been inevitable that disputes would arise and that agreements for attainment of common ends would be found necessary. Unlike the situation in European and Asiatic waters, only two nations have been concerned in practically all of these cases. Because of this simple relationship and because of the ideals and interests held in common, real progress has been made. Definite and seemingly permanent settlements have been reached for the sealing, halibut, and Passamaquoddy Dam questions. The treaty for rehabilitation of the sockeye run in the Fraser River seems near to completion, and proposals have been made for a treaty controlling the haddock fishery of the Atlantic.

Of these the sockeye treaty deserves special mention. After more than 28 years of negotiations and the writing of three treaties, that advanced in 1930 has been signed and ratified by both countries. The United States, after discussion by local interests, has ratified subject to three reservations which Canada has not as yet acted upon. The treaty provides for the necessary research on the life history, for a division of the catch in equal parts to the two fleets, gives the Commission power to prohibit the taking of sockeye in both international and territorial waters which they frequent enroute to the Fraser River, and gives it power to regulate the mesh used during the season for King salmon. The reservations specify (1) that the treaty powers shall not be used to authorize gear forbidden by the laws of Washington and Canada, (2) the postponement of any regulation for eight years, and (3) the creation of advisory committees of five from each country.

It will be remembered that the halibut convention had a similar history of prolonged agitation and negotiation from 1914 to 1924, despite the almost unanimous desire for conservation by a close season. Although the treaty has had acknowledged and continued success in rebuilding the stock of halibut, it would have been better had rational control been adopted prior to the extensive depletion that now must be made good.

The success of the treaty is apparent in increasing the stock of halibut, so that, for instance, the catch per unit of gear on the most depleted grounds has increased from 36 pounds in 1930, when actual regulation began, to 60 pounds in 1935. This means the creation of a breeding reserve and the increase of spawn produced for the future. But the treaty is successful in another way as well, as it is steadily and surely building up our knowledge of what research and legal structure is necessary to efficient regulation. Experience and altered conditions have required the rewriting and readoption of the treaty in 1930. At present a unanimous demand exists for further revision of the treaty to alter the provisions for terminating the season by control of clearance rather than simple closure and to permit the proper disposal of halibut taken incidentally to other fisheries. These changes and suggestions of change indicate the extent to which this pioneer treaty is developing practical methods of international cooperation.

A brief review of other fisheries in which international cooperation may become necessary shows that it would be of the utmost future value to develop some procedure whereby agreement between interested groups in the countries concerned could be reached more speedily, completely, and correctly.

A treaty to preserve the haddock fishery has been recommended by the North American Council on Fisheries Investigations. The Council is composed of fisheries officials advised by the experts who have been carrying on the investigations in the North Atlantic. Their evidence is that the haddock shows evident depletion and that the vessels engaged therein are each year going much farther for their catches, about twice the amount being taken from the Nova Scotia banks in 1934 as in 1933 by American vessels. The need for adoption of larger-sized meshes to enable the smaller fish to escape is stressed in their statement, as approximately two-thirds of the haddock are taken by the small mesh used, destroyed and discarded.

The concern of both Canada and the United States in fresh water fisheries along the border is expressed as follows in Appendix III to the Report of the Commissioner of Fisheries, Progress in Biological Inquiries, 1934, page 371:

"One of the most urgent needs on the Great Lakes today is concerted action by the various Commonwealths, both in this country and in Canada, to regulate and protect the commercial fisheries of the Great Lakes. Since 1927 the Bureau has cooperated with the various Commonwealths in some ten interstate and international fisheries conferences. During this period the Bureau, in cooperation with various State conservation departments, has concentrated its scientific research on the Great Lakes on those controversial practical problems that previously had prevented enactment of uniform regulation. In spite of the vast amount of scientifically collected data available to support the recommendations adopted at the conferences,

little progress has been made in the enactment of the recommendations into laws.

"The necessity of uniform regulation is obvious from the fact that, in many cases, fishermen from two states or two countries depend on the same population of fish. Lack of uniformity not only causes much unfair competition between fishermen of adjoining states but also fails completely to give the fish the necessary protection. Twelve species of fish have been either exterminated or seriously threatened. The blackfin bloater and salmon of Lake Ontario have been completely exterminated. The sturgeon, blackfin, chub, and Lake Erie cisco no longer support a commercial fishery. The other six species of chubs are severely depleted, and the whitefish is seriously threatened with commercial extinction. The final result of continued lack of uniform regulation appears to be obviously indicated by what has happened in the past."

The Lake Erie Advisory Committee is composed of a representative from each of the States fronting Lake Erie and from the Province of Ontario. This committee was appointed some years ago, and its duties are to study the various problems on Lake Erie and to make recommendations with respect to uniform regulations of the commercial fisheries of this lake.

Since the last meeting of the Society at Tulsa, this committee has held two conferences at Washington, D. C. Every State fronting Lake Erie and the Province of Ontario was represented.

At these conferences the representatives agreed that recent attempts by the various States and the Province to enforce uniform regulations on Lake Erie were failures and that the best solution of the problem would be to turn over the regulation of the Lake Erie fisheries to an international commission governed by a treaty with Canada. There was considerable discussion concerning the mechanics that should be followed in the United States in reaching this objective. It was finally agreed that a list of regulations should be drawn up to be considered for inclusion in a proposed treaty, that these regulations were to be submitted to the director of the conservation departments involved, and that these officials discuss the proposed regulations and the question of international control with their commercial fishermen. The results of these conferences with the fishermen would then be discussed at a meeting of the Lake Erie Advisory Committee and final recommendations adopted by the committee. If international control is then agreed upon, the governors of each State could then petition the Secretary of Commerce, who in turn could make arrangements through the Secretary of the State Department to contact the Candian Government. Due to various reasons no definite action has yet been taken on these recommendations.

At Toronto, Ontario, a conference was held on March 16 and 17, 1936, attended by representatives of the Province of Ontario, the State of Michigan, and the United States Bureau of Fisheries. It was held for the purpose of discussing uniform regulations of the commercial fisheries of Lake Huron. An agreement was reached concerning the uniform size of mesh used for chubs in Lake Huron and a uniform size limit for perch for Lake Erie.

An International Fact-Finding Commission to investigate the pike-perch fisheries of Lake Champlain has been appointed by the United States and Canada and has been at work for several years.

There has been much discussion of the need for a joint pollution survey of the Rainy River between Rainy Lake and the Lake of the Woods. The discharge of waste material from the paper mills and of domestic sewage at International Falls and Fort Francis is alleged to have nearly eliminated the natural reproduction of sturgeon and wall-eyed pike, seriously affecting the fisheries in the Lake of the Woods.

On the Pacific Coast it is apparent that other fisheries than those for the sock-eye salmon of the Fraser are of international interest and may arouse discussion of joint action at some future time. The spring salmon of the Columbia migrate along the coasts of British Columbia and Washington to spawn in both United States and Canadian rivers and to form the object of a fishery by both nations.

The pink salmon taken in Puget Sound waters are many of them supposed to spawn in the Fraser watershed of Canada. The great pilchard fishery is prosecuted by both Canada and the United States. The opinion has been expressed by scientists that the stock drawn upon is the same, and if conservation is ever agreed upon, international action will be necessary. The black cod fishery is already considerable in both Canada and the United States, and fishermen regard the species as much scarcer than formerly. The drag net fishery for flounders and soles is steadily growing, with as yet a large untouched stock, but joint exploitation of the same grounds by the two countries is expected.

On the southern coast line the extension of the tuna fisheries southward from California ports has brought up the possibility that international agreements may be thought desirable with our neighbors there. It will be remembered that a treaty was signed with Mexico in 1925 to control smuggling, but was soon after terminated. It contained provisions for exchange of information as to clearances and suspected smuggling; for regulation of migration and deportation and the creation of an International Fisheries Commission with regulatory powers.

In all of these cases it is apparent that international understanding and at times joint action are needed. Yet such understanding and action have been difficult to bring into being without creation of some procedure other than that of the informal discussions of interested parties. In the opinion of your Committee the development of such procedure is one of the major needs at present. It may not in every case involve creation of treaties but should at least provide machinery and a joint research basis for formal discussion and agreement of those interested on either side of the border.

In marine fisheries the need for progress in this line is specially urgent. The existing treaties, seal and halibut, have been outstandingly successful, and serve as precedents. But the simple direct relationship between two friendly nations which has made the latter pact possible may not continue indefinitely. Such cooperation has not been possible to arrange where a number of nations share such a highly competitive and economically complex fishery as that of the North Sea. The steady expansion of nations to more distant fishing grounds because of limited or reduced production by the nearby banks, has been hastened by the modern evolution of methods of preserving and marketing. The day is not far distant when other nations will seek to enter waters Canada and the United States now exploit alone or jointly. When that day comes it will be most necessary that the basis of successful regulation and cooperation be already laid so that it may be firmly supported by the two nations.

It is therefore the recommendation of your committee that it be adopted as a definite policy of the Society to further develop and support the cordial and successful cooperation of the nations already sharing the fisheries of this continent, and that it express to the governments of this continent the immediate need for creation of definite procedure which will hasten this end and which will establish in definite form joint policies, before they are adversely modified by the march of events.

Your Committee also has the following specific recommendations to make:

That thorough consideration of treaties to deal with the haddock fishery of the Atlantic and the fisheries of the Great Lakes be initiated at an early date by the Governments concerned; that the Governments of Canada and the United States be asked for early action upon the already pending convention regarding the sockeye fishery of the Fraser River and upon the proposed changes in the halibut treaty.

W. F. THOMPSON, *Chairman*
W. A. CLEMENS, British Columbia
HERBERT DAVIS, California
FRED J. FOSTER, Washington
JAMES A. RODD, Canada
THADDEUS SURBER, Minnesota
FRED A. WESTERMAN, Michigan

DR. THOMPSON: In presenting this report I would like to point out to you that here is a practical means of laying a foundation for future peace on the North American continent. We might develop this splendid cooperation and peaceful relationship with Canada to the point where it will be of indefinite and permanent value.

THE PRESIDENT: Thank you for this excellent report. I know of no one in this or any other country who is better posted on international relations in the fisheries than Dr. Thompson.

COMMITTEE ON COMMON AND SCIENTIFIC NAMES OF FISHES

CARL L. HUBBS

Nothing would give me greater pleasure than to be able to present a report at this time from the Committee on Common and Scientific Names of Fishes which would be in line with the uniformly splendid reports which have been given by the Vice-Presidents and the Chairmen of the other committees. I can only report that we have given considerable attention to the matter of the formation of a list, and that we hope sincerely to be able during this coming year to escape the field expeditions and other business and activities which have prevented us from carrying to completion a report on common and scientific names which could be accepted by the Society and used to help to standardize these names for the reasons which have already been stressed, and which I think are well appreciated by this group. I think I can say that during the coming winter we will let nothing interfere with the completion of this task.

REPORTS OF SPECIAL COMMITTEES

REPORT OF COMMITTEE ON AMERICAN FISH POLICY

E. L. WICKLIFF

[The chairman presented a further report, which the Committee recommended be mimeographed and distributed to the members of the Society for study and comment, but not to be printed in the transactions. (See pages 27 to 29, 1935 Transactions, for original outline).]

MR. WICKLIFF: I move that the report be accepted and the committee continued for another year.

THE PRESIDENT: You have heard the report of the committee; it is moved that the report be accepted and the committee be continued for another year. What is your pleasure?

(The motion was seconded and carried unanimously.)

REPORT OF POLLUTION STUDY COMMITTEE

TALBOTT DENMEAD, *Secretary*

THE PRESIDENT: The next is the *Special Committee on Pollution,* of which Hon. Harry B. Hawes is the Chairman. Senator Hawes reports he is unable to attend on account of illness, and sends his regrets. He wants the members to understand he has not lost interest in the work, but illness makes it impossible for him to be here. The secretary of the committee, Mr. Talbott Denmead, of Washington, D. C., is here; may we hear from him?

MR. DENMEAD: Mr. President, I do not think this gathering has any more important subject to consider than the cleaning up of the polluted waters of North America. This is not a report of your Pollution Study Committee; it is merely a preliminary report of the secretary of the committee. All the members of this committee, composed of fifteen members of the Society, have been working collectively as far as possible, and individually just as hard as they can.

Since our last meeting in Tulsa, Oklahoma, a year ago, much polluted water has passed under many bridges, resulting in the death of many fishes; there has been much talk about doing something about it, but like Mark Twain's famous remark about the weather, nobody has done anything. Little progress has been made in actually and permanently removing pollution; true, some abandoned mines have been sealed in Pennsylvania and nearby states, a few city disposal plants have been planned, and in some instances completed. Lots of talk about more investigations has been heard (a favorite method of the polluters for delaying action), but as a whole we are just about where we were a year ago; while we have cleaned up in one spot additional water contamination has occurred in others; while we talk, instead of playing a fiddle like Nero, the fish die.

Pollution may be stopped in a way that is perfectly satisfactory to health officials, or to a point where it doesn't destroy cattle; but from the fish viewpoint it may not be so good; an industry with every good intention tries to prevent pollution by depositing its poisonous refuse in vats or other receptacles on the land, but an accident, an unusual storm or some act of man, suddenly releases a large quantity of poison into the stream; it is in concentrated form and in bulk—the fish are killed for miles down stream. Reports of dead fish reach the ears of state authorities, investigation is made, the parties responsible are very sorry, and promise not

to let it happen again; but the fish are all dead, and it will take two or three years to replace them. The angler can wait. By the time his interest and work, and that of the State authorities, at considerable expense have brought back the fish supply to almost normal another "accident" occurs, and the angler and the state conservation authorities can begin all over again. How long, Oh, Lord, how long? Is it not time something is done besides investigating, leaving it to health departments and inadequate or unenforced state laws to clean up our streams?

Someone has said the industries have always polluted our streams and have a right to continue to dump their refuse into the public waters. They are wrong. A man can obtain title to a piece of land by eminent domain, or a right of way by prescription, but he cannot obtain a right to maintain a nuisance.

The States for years and years have been continuously trying to stop pollution, with little success. Either the laws were not sufficient or not enforced, or the polluters were too big; fish continue to die off from poisons dumped into public waters—*sinful* WASTE. Scientists are still investigating, and can continue to do so for generations, but their findings *alone* will not save fish.

What then? Some authority extending beyond the jurisdiction of the locality where pollution occurs, big enough to control an offending corporation with pull, and covering all the polluted water, whether in one or more states, something with a punch in it to be used if and when necessary, that can actually make a polluter stop polluting when reason fails.

Your committee members have various views on the subject. Certainly a majority favor Federal control of some kind; many favor the Lonergan Bill, as is, or with slight amendments. Your secretary does not mind who knows it; he is in favor of the Lonergan Bill, which was favorably reported by the Senate Committee with slight amendments at the last session. Let me quote you a few extracts from letters recently received from members of our committee.

"No legislation will be of any value in the move to suppress stream pollution unless it incorporates the following three principles: *First,* that it provides a clearing-house for information, and an opportunity of cooperation between the Pollution Board and the polluters; *Second,* that it provide means of financing municipal sewage and trade waste, disposal plants by loans of Federal funds, and so far as municipalities are concerned, by a grant of part of the cost, on the theory that it is as much the concern of the Federal government to safeguard the quality of the water as it is to dredge out channels; *Third,* that it gives power to the pollution abatement agency to compel polluters, who will not cooperate voluntarily, to do so."

I might say that the only one of the bills pending in Congress incorporating these three things is the Lonergan Bill. I might also add this bill does not conflict with the doctrine of State's rights, for the Federal control only extends to navigable waters, and such tributaries as affect navigable waters. Beyond that a Federal board cannot and should not go.

I quote from another reply: "It seems to me that the most important matter in the pollution situation is the proposed national legislation....I am thoroughly convinced that any legislation which does not give authority to initiate action in some Federal agency will not accomplish the purpose desired....There are certain fundamental features in the Lonergan Bill, back of which I believe we must stand if real accomplishment is to result. There are other features in which modifications might well be made to meet objections."

Another: "May I frankly say that in my opinion the committee has not discharged its full duty to the American Fisheries Society and to the country in the reports which have been made. Through outside pressure it has shown too much of the weak and foolish policy of pitying the evil-doers and neglecting the public rights which have been violated and public values which have been destroyed.... I would suggest that arrangements be made to have the committee embark at once on an actual study and discussion of the situation. The work should begin

in September in order that proper progress may be made before the matter is taken up in the coming session of Congress."

In considering this suggestion your secretary advises some reorganization of the committee. Several members advised that they had no suggestions to make in regard to a report.

THE SECRETARY: I suggest, if it is the wish of the Society, that it would be well to do as we have in the case of the special Committee on *American Fish Policy,* namely, by resolution to extend the life of the committee for another year.

THE PRESIDENT: Do I hear a motion that the committee be continued for another year?

MR. LOCKE: I so move. (Motion seconded and adopted.)

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE DIVISION OF FISH CULTURE

T. H. Langlois

Nature-lovers, sportsmen, farmers, industrialists, educators, and others who are sincerely interested in the conservation of natural resources have visions of a politically-free administration which can function so effectively that the natural resources of our country can do the most good for the most people for the longest period of time. This vision has not been realized, because in practice the administration of conservation is a matter of conducting activities along those lines which will ease the specific pressures brought to bear by these same nature-lovers, sportsmen, farmers, industrialists, and educators.

Many of the problems of conservation have to do with the restoration of wildlife, and attempts to solve these problems must be based upon knowledge of wildlife requirements. Biologists, who possess this knowledge, are anxious to promote the cause and incidentally sell their services, but they are intolerant of administration by this splitting of differences of group interests and have ambitions to revamp and take over the functions of administration. To the administration the group of biologists represents a tool which might be useful in adjusting pressures but it also represents another group interest whose pressure requires adjustment. The administration will employ the talents of the scientists whenever it can be sure that the scientists will do the things the administration wants to have done.

Scientists should help the administration by finding solution to the smaller problems and should aim to supply the groundwork of basic principles only as fast as the administration is ready to receive it. This method does not engender sales resistance, in which it differs from the method sometimes employed of creating public sentiment to force the administration to employ scientists. The recent history of fish restoration efforts may be cited as an illustration of the attempts of biologists to take over the function of administration instead of rendering the type of services for which they are best qualified.

For the last half century fishermen have become increasingly dissatisfied because the fish-producing acreage of public waters per fisherman has decreased as the number of fishermen has increased, and because the acre-yield has been reduced by overfishing and environment ruination. Attempts at improving the situation have consisted primarily of limitations of take and restocking with fish from hatcheries and ponds. To meet the demand created by this conception of the needs of the situation, fish culturists have developed practical methods of producing fish by combining study of the habits and requirements of the fish with attempts to meet the needs as fully as physically and economically possible. The operation of a fish hatchery or fish farm involves the construction and maintenance of an establishment wherein suitable conditions prevail for the welfare of the kinds of fish to be produced, and the management of a stock of fish which undergoes an annual turnover, with a periodic increase in number and size of individuals, maintenance of an effective brood stock by regular replacement of old with new breeders, and harvest of an annual crop.

Biologists have been studying fish habits and life-histories, analyzing aquatic environments and experimentally attempting to determine the nature of the effects of some environmental factors upon the fish. Much of this work has been basic research but has been designated "theoretical and impractical" by the fish culturists. The demand for something "practical" has led biologists in recent years to conduct intensive surveys of particular water areas, and these single-season peeps at

the problems have led to realization that the constantly changing conditions prevailing in aquatic habitats require continuous study. Based upon such study it is believed possible to manage the physical conditions of water areas and stocks of aquatic organisms in such manner as to bring about the production and permit the harvest of the maximum annual increment of fish. Actually this is an attempt to apply the same principles to native stocks in natural waters which fish culturists have applied successfully under the controlled and limited conditions of a fish farm or hatchery.

The restoration of good fishing by increasing the acre-yield of fish of suitable water areas by management is a large scale farm management program in which the phase of animal husbandry is one for which the fish culturists have supplied most of the limited background of principles and practices. This background must be built up if aquiculture is to proceed on the same sure footing as agriculture. Since the need is urgent, time can be saved by impressing experts from agricultural colleges and experiment stations who have applied biological facts and used the scientific approach to the study of production of particular types of land crops. Underwater soils and methods of maintaining, raising, or restoring their fertility should be studied by soil experts; farm crop experts and botanists should cooperate in developing methods of managing aquatic plant crops; animal breeding experts should work towards the production of improved fish and other aquatic stocks; physiologists should be employed to extend our knowledge of the normal and abnormal physiology of fishes; biologists should extend our knowledge of the life histories of the more important species of fishes and other aquatic organisms; experts on economics should assemble and interpret data on trends in the fisheries, the marketing of aquatic products, etc.

State conservation departments should be convinced of the need for these types of research and should subsidize them. State fish farms and hatcheries should be assigned the additional function of experimentation, and researchers should utilize the opportunities presented for studying the factors influencing fish production under the controlled conditions prevailing in jars, troughs, raceways, and ponds. The results of the research should be immediately tested by application, and successful practices should be standardized and applied on a large scale throughout state waters. Application must be kept from preceding the establishment of facts by research, and research must be kept from taking inconsequential tangents. A continuous inventory of aquatic conditions based upon available knowledge of significant factors and of aquatic populations should be begun at once, and extended to include additional items as quickly as indicated by research.

This research program would be supplying the groundwork for extensive activities on all public fishing waters of the State. The execution of such a program would cost more money than most state conservation departments now obtain by selling fishing licenses, but more funds could be brought in by licensing additional classes of fishermen. The research program would provide employment for many non-politically minded investigators, as well as enough skilled and unskilled labor to meet political requirements.

It is probable that the inauguration of such a program would make it possible for the administration to pay first attention to the natural resources and obviate much of the necessity for attending to differences in interests of group pressures. The efficient administration of such varied and extensive functions is a job requiring an exceedingly capable business man with social intelligence, and scientists as a rule are characterized by their abstract intelligences. The demand of the scientists to be placed in charge of administration should be changed to a plea for an administrator who can make most effective use of their talents, provide opportunities for them to do significant work, appreciate their services, and remunerate them accordingly.

REPORT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

A. S. Hazzard

During the past year there has been an increased interest in the field of aquatic biology as related to fisheries work. The American Wildlife Institute completed its organization and proposed an international Wildlife Conference which was called by President Roosevelt in February. Research in fisheries biology had a prominent part in the technical program. The North Central States Conference of Wildlife Technicians was organized at Urbana, Illinois in December to facilitate and coordinate research in fish and game. At the regular meetings of the American Society for the Advancement of Science, the American Society of Limnologists was officially recognized as an affiliated society. This newly organized group has a charter membership of 221 scientific workers interested in various phases of the study of inland waters.

Since we last met there has also been at least a slight increase in interest in teaching and research in aquatic biology at the institutions of higher learning in America. Courses in Limnology and Ichthyology have been added to the curricula of certain colleges. The National Research Council has allotted grants-in-aid to several important studies in fisheries biology.

Also during this period a rather considerable number of appointments of aquatic biologists have been made by federal and state conservation agencies, many of these in fisheries work. According to announcements the majority of these positions required training in the fundamental fields of Aquatic Biology and in the various phases of fishery research. Many of these appointees will be expected to solve problems in hatchery technique as well as the numerous and varied fishery problems of lakes and streams. Are they properly equipped for such work? Adequate training for these jobs is not found in the curriculum of any college in America.

Land grant colleges in nine states have recently introduced courses in Wildlife Management through the cooperation of the American Wildlife Institute, the U. S. Bureau of Biological Survey, and the state conservation departments concerned. Other colleges have developed similar instruction but with few exceptions the training is wholly devoted to *game management.*

When it is considered that by far more people in America are interested in fishing than in hunting, it seems strange that the need for training men as fish researchers and managers has not been recognized. Training in the basic fields of aquatic biology is necessary, but it must be followed by training in the fundamentals of modern aquicultural research.

REPORT OF THE DIVISION OF COMMERCIAL FISHING

R. H. Fiedler

At the outset of this report I would like to discuss briefly the present status of the fishery industry to give you a picture of conditions obtaining in its various branches.

According to present available data the commercial fisheries in 1935 showed considerable improvement over conditions obtaining in the previous year. This was most pronounced in those branches of the industry concerned with canning or otherwise processing fish for market, although some branches of the industry dealing in fresh fish all improved. As a result our fishing fleets spent more time on the fishing banks and less time docked at the pier, and employment in the processing plants was on a more regular basis. This increased activity did not necessarily enlarge the number of employes in the industry; rather it gave those already employed an opportunity for more steady work with a correspondingly larger pay envelope.

The American consumer apparently ate more fish in 1935 than in 1934, as is indicated by the increased production in many branches of the industry.

At Boston and Gloucester, Massachusetts, the landings of fish were up 25% in 1935 over the previous year. In this connection it is interesting to note that with the scarcity of haddock on the banks near these ports efforts have been successfully made to market types of fish occurring in these nearby waters which formerly found small sale, including the rosefish and the whiting or silver hake. As a consequence the landings of these fish at New England ports are increasing by leaps and bounds.

In the freezing and cold storage trade the fish freezers were literally bulging with fish; for the pack of frozen fish in that year was the largest on record, and withdrawals of fish from the cold storage plants were about one-third greater than during 1934.

The fresh and frozen-packaged fish industry also had a record year in 1935, with a production exceeding that of any year since the inception of the business in 1922.

The canned fish branch of the industry in some instances reached a new high in production in 1935. More tuna were canned in California than in any previous year, as was the case with the pack of canned mackerel in California. The pack of sardines was the largest in California since 1930, but about one-third less than in 1929. The canning of mackerel in California is of recent origin, the pack finding a market mainly in the southern states. Here it competes with the lower grades of canned salmon. While the packs of tuna and sardines increased, the price per case relaxed during the year. That for canned mackerel increased, however, no doubt because of the exceptional demand for it in the South.

The fish oil industry showed a greatly increased production in 1935 over 1934, due for the most part to the large production of the sardine factory ships operating off the Pacific coast. Prices remained firm in 1935, being considerably advanced over those for the previous year.

In 1936 the canned salmon industry produced the largest packs on record.

From the foregoing it will be noted that our commercial fishery resources, after a lapse of several years, are being fished most intensively. Now concern is being evidenced as to the future productivity of some species. However, with the constant improvement in the efficiency of fishing gear, such as the submarine trap, still used in some waters of the Great Lakes; with the adaptation of certain types of gear for capturing fish, such as the use of the otter trawl for taking whiting, formerly caught mainly in shore trap nets; with the discovery of the winter home of certain species now resulting in the capture of these species in both summer and winter, as is the case with the scup, croakers, etc., taken in the marine waters of New Jersey, Maryland and Virginia; with the increased use of the factory ship in prosecuting some fisheries at sea; and with the intensive fisheries now prosecuted for fishes formerly thought unmarketable, such as that for the rosefish off New England—it has become difficult for the biologist to keep abreast with the rapidly changing character of our fisheries and to make the necessary investigations to ward off depletion.

Fishery Cooperatives

During 1935 many groups of commercial fishermen became interested in forming cooperative societies. One operated in Maine to find an outlet for the catches of inshore fishermen. Another was formed and operated in North Carolina. On the Pacific Coast several cooperatives of salmon fishermen continue to function, and recently producers of oysters in the state of Washington have been considering the merits of such societies in aiding them to find an outlet for their product. Also, California has in operation several types of fishermen's cooperatives covering crabs and sardines.

National Legislation

During the seventy-fourth Congress various pieces of legislation were passed having a bearing on the commercial fisheries. Included are the Robinson-Patman

Act, the Social Security Act, an act to give effect to the Whaling Convention, and a Ship Subsidy Act. Defeated or not acted upon were several shipping bills affecting fishing vessels, the Bland Bill to provide for economic fishery studies by the federal government and a market news and extension service, proposed legislation affecting the operations of the sardine factory ship, and provision for a biological study of the California sardine fishery.

Other measures adopted were reciprocal trade agreements with several foreign countries, many containing new provisions for entry of fishery products in to this country under more lenient terms, and the duty was raised fifty per cent on imports of frozen swordfish.

Advertising Campaigns

During the past year several branches of the industry conducted group advertising campaigns. One was conducted by the Oyster Institute, and another by the Association of Pacific Salmon Fisheries. In addition many individual concerns advertised their products, through cooking demonstrations and publication of a cook book for fish. The United States Bureau of Fisheries aided in this work by supplying information as to the food value of fish and shellfish, and also by publishing a booklet on practical fish cookery and another on oysters, both of which found wide circulation.

Depletion of Species in Certain Areas

The depletion of many important species of fish taken in the Great Lakes has resulted in the introduction of sea fishes to the people of the mid-west who formerly consumed great quantities of lake fishes. For instance, on a recent visit to several mid-western cities I found that rosefish taken off New England is the second best seller in many retail stores. Also the whiting taken off Cape Cod is consumed in tremendous quantities in the mid-west, especially in St. Louis. In other words the markets formerly supplied by the fishermen of the Great Lakes are now obtaining fish from Atlantic coast fishermen. In the meantime, no headway apparently can be made by the Great Lakes states in developing coordinated regulations to sustain production of the fisheries of the Great Lakes.

In another instance we find that Baltimore is being supplied with crab meat from Louisiana, while Maryland and Virginia seem unable to develop measures to sustain the production of the Chesapeake blue crab.

Statistics

During the past year little headway has been made in the collection of more current figures on the various branches of the fishery industry. The United States Bureau of Fisheries has endeavored from time to time to enlist the cooperation of the state fishery agencies in the collection of fishery statistics, for the activities within their respective states, in such a manner that those collected will be uniform and enable the Bureau as a clearing-house to publish the figures in a uniform manner. In this work we have secured unusual cooperation from some of the states, such as the Great Lakes states, Maryland, Virginia, and the Pacific coast states. It is most desirable that other states take similar action. However, because of curtailed appropriations during recent years some of these states have been unable to cooperate. It is hoped that before the next meeting of the Society more states will be able to engage in this type of basic study.

Economic Studies

Last year unusual interest was shown in the conduct of economic fishery research by various agencies, which has been of considerable aid to the industry. Some of the more outstanding work includes a survey of the marketing of fish by Florida fishermen, sponsored by the Florida state fishery agency; a study of the

marketing of fish in Durham, North Carolina, conducted by Duke University; a study of the marketing of fish in the San Francisco bay area, and an economic study of the halibut fishery and industry, the latter two by the United States Bureau of Fisheries.

Technological Research

Research in the field of fishery technology continued at an accelerated pace. Whereas the industry formerly has been reluctant to improve its processes and methods, during the past year several radical technical changes were made. In one instance technique developed by the Bureau of Fisheries has been used to determine the freshness of fish, landed by the fisherman, in an effort to put a quality product on the table of fish consumers. In another instance members of the menhaden industry have adopted a new method for preserving the fish aboard vessels while fishing at sea, in order to bring in a better product. Boxes are now being used in many fisheries instead of barrels, which tends to the delivery of better quality of fish to market.

Researches by the Bureau to obtain new sources for vitamin-bearing fish oils have revealed the oil from the swordfish liver to be the most potent in vitamins A and D, being one hundred times more potent than the U. S. P. standard reference cod liver oil.

The use of fish livers as a source of vitamins has resulted in greatly increasing the income of many fishermen. In one case it is estimated the fishermen of the Pacific coast were enriched last year by $1,000,000 from the sale of fish livers alone.

Studies in canning fish have opened opportunities to develop new fisheries, especially a sea mussel industry on our Atlantic coast, a razor clam industry, and an extended blue crab fishery. Time will not permit a recital of other technological developments.

In closing I would like to bring to your attention the fact that the commercial fishermen and fish dealers need the help of the federal and state governments to raise this branch of our economic structure to its former plane. While the revenue derived from the industry does not bulk as large in our national economy as it did in colonial times, nevertheless fishing is an honorable and upright vocation. I would especially like to urge the state fishery agencies of the thirty-nine states having a commercial fishery to take a greater interest in improving the economic conditions of the industry. Instead of concentrating, as is often done, on merely extracting a license fee from the fishermen and later sending around a patrol boat or warden to see whether the state fishery regulations are being regarded, I urge you to do greater work in helping them to market their catch, as many state agricultural bureaus are aiding the farmer to market his produce. I urge you to try to help the fishermen in a technical way to improve the quality of the fish shipped to market or in developing new products. I urge you to give them something more than just the right to fish in your state waters.

REPORT OF THE DIVISION OF ANGLING

S. B. Locke

The most outstanding development in the field of angling is the great increase in anglers, or perhaps more properly in days of angling, due to the fact that there is a distinct increase in the frequency and duration of angling trips. Unemployment, or restricted employment, on the one hand, and an improved financial situation on the other, contribute to this.

The recent report by the United States Bureau of Fisheries on license sales shows an increase of over $422,000 in license fees, with a total of over five million fishing and combination hunting and fishing licenses for 1935. Due to the conditions mentioned above, this does not show the full increase in drain on the fishing resources.

Every indication, such as license sales and volume of tourist travel, points to a most substantial increase during the present year.

Outside of the drought afflicted sections, fishing conditions and fishing success have been generally good. Excessive hot weather and resulting high water temperatures adversely influence the catches.

A relief to the drain on present water areas has been the development in several states of new or restored lakes. There has also been a turning to new sources of sport in ocean fishing and in the Great Lakes trolling for lake trout. This deep trolling for lake trout offers very definite possibilities for transferring a considerable production of fish from a commercial to a more valuable use for sport fishing. The demands for services in connection with the sport fishing offer the people now employed in commercial fishing a more remunerative occupation.

A new possibility is also presented in the restoration of trout production to depleted areas of the Great Lakes in the vicinity of cities to contribute, on a sound economic basis, to public welfare. In former days lake trout were taken along the Chicago waterfront. Consider the possibilities of an area reserved for game fishing and built up for production of sport fish from Chicago to Waukegan, in an area now producing a meagre commercial production. This exemplifies the necessity of making available all water areas possible of fish production and of developing both the production of such areas and the establishing of new water areas if the growing demands for angling are to be met.

An encouraging feature is the interest in more sporting angling methods. There is a noticeable increase in fly-rod fishing. Streams segregated for fly fishing, instructions for fly fishing on especially designated streams, and waters reserved for the exclusive use of ladies, are all services raising the standards of sport and contributing to a greater enjoyment of the sport with less drain on the supply. Particularly significant is the designation of streams, which are maintained well stocked, where fishing is encouraged but with an extremely low limit set for fish which may be killed. This teaches the true basis of the sport which is not measured by the fish killed.

I see the problem of supplying the demand for sport in angling as having two distinct features; one, the problem of the fish culturist in producing more fish, and the other, changing the attitude of the fisherman to intensively idealize their sport to bring equal satisfaction and enjoyment with less killing of fish.

THE PRESIDENT: Thank you, Mr. Locke. Is there any discussion on this report?

MR. KENNETH A. REID (Pennsylvania): I want to support what Mr. Locke has said about reducing the kill. As some of you know, I am very fond of fishing, but I am not fond of killing fish. I have just been fishing for about two and a half months in different places, and I am more thoroughly convinced than ever that the fly in the ointment of this fishing problem is Mr. Average Fisherman. The fish culturists, the management men, the biologists and all others interested in the work may do the best they can, but in the final analysis much of their effort will be nullified if we cannot sell to the average fisherman the idea that it is desirable that he change his attitude and get away from the objective of taking the legal limit on all occasions and bringing home a lot of dead fish.

APPOINTMENT OF COMMITTEES

Auditing—Thaddeus Surber, *Chairman*, M. C. James, Robert Hayford.

Resolutions—I. T. Quinn, *Chairman*, A. S. Hazzard, M. M. Ellis, James A. Rodd, Grady McCall.

Time and Place—Arthur Clark, *Chairman*, Carl D. Shoemaker, Herbert Davis, J. D. Chalk, James A. Rodd.

Nominations—Fred Westerman, *Chairman*, E. Lee LeCompte, H. H. MacKay, Frank B. O'Connell, Emmeline Moore.

Publications—J. A. VanOosten, *Chairman,* Leonard Schultz, W. J. K. Harkness, John R. Greeley, Paul R. Needham.

Constitution and By-Laws—Talbott Denmead (Special committee of one).

Special Committee on Transportation—William J. Tucker, *Chairman,* I. T. Quinn, Senor Juan Zinser, Herbert C. Davis, Carl D. Shoemaker. (A special committee to arrange for transportation to the 1937 meeting).

Special Committee on Journal—T. H. Langlois, *Chairman,* Elmer Higgins, W. J. K. Harkness, David Belding, George C. Embody, A. S. Hazzard. (This special committee was appointed to consider the wisdom of the Society publishing a journal other than the annual transactions, to report at the next annual meeting.)

REPORTS OF COMMITTEES

AUDITING COMMITTEE

THADDEUS SURBER: The Auditing Committee has checked the books and records of the Secretary-Treasurer for the fiscal year ending June 30, 1936, and found the report as issued to be correct.

It is again recommended that the allowance for clerical and stenographic services for the year 1936-1937, exclusive of expenses in connection with the preparation, proof reading, and indexing of the Transactions, be the same as last year, $350.

DR. BANGHAM: I move that the report be adopted. (The motion was seconded and carried unanimously.)

COMMITTEE ON RESOLUTIONS

MR. QUINN: Mr. President, your Committee on Resolutions presents the following for the consideration of the Society:

The Late Henry O'Malley

BE IT RESOLVED, That the American Fisheries Society express its deep sorrow at the passing of Henry O'Malley, who died suddenly at Seattle, Washington, on April 24, 1936, at the age of sixty years. Mr. O'Malley was a faithful member of the Society for thirty-five years and served as its president for the annual term beginning in 1917.

Practically all of Mr. O'Malley's life was devoted to public fishery activities, entirely in the service of the Federal Government. His career began as laborer at the hatchery at St. Johnsbury, Vermont, his birthplace. He later served at Leadville, Colorado; Baker Lake, Washington; Baird, California; and at Clackamas, Oregon; then as field assistant in charge of Pacific Coast operations, chief of the Division of Fish Culture, and finally as United States Commissioner of Fisheries, to which position he was appointed by President Harding on May 13, 1922, and which he filled for about eleven years until April 15, 1933. Thereafter he was superintendent of the station at Baird, California, until August 31, 1934, when he retired for disability after public work in the fisheries covering approximately thirty-seven years.

Mr. O'Malley was a practical fish culturist, but was interested in all phases of fishery work, including scientific, technological, and statistical research. He was especially interested in restoring the great salmon fishery of Alaska and in placing that industry upon a stable and enduring basis.

Mr. O'Malley was noted for his genial nature and ready wit. He had a wide circle of acquaintances and friends throughout the country. He was the author of many articles on various phases of fishery work.

Further resolved that a copy of this resolution be sent to the members of his family, to whom we express deepest sympathy.

International Cooperation—Action Upon Treaties and Conventions

RESOLVED, That it is a definite policy of the American Fisheries Society to further develop and support the cordial and successful cooperation of the nations already sharing the fisheries of this continent, and that it expresses to the governments of this continent the immediate need for creation of definite procedure which will hasten this end and which will establish in definite form joint policies, before they are adversely modified by the march of events, and

BE IT FURTHER RESOLVED, That the American Fisheries Society ask the governments concerned to initiate at an early date a thorough consideration of treaties to

deal with the haddock fishery of the Atlantic, and the fisheries of the Great Lakes; and that the Society ask the governments of the United States and Canada for early favorable action upon the already pending convention regarding the Sockeye fishery of the Fraser River and upon the proposed changes in the halibut treaty.

California Sardine

WHEREAS, The California sardine is threatened with serious depletion by the operation of floating reduction plants on the high seas; and

WHEREAS, Such depletion of the sardine would menace not only the sardine industry but also the great commercial and game fisheries based on species which feed on the sardine;

BE IT RESOLVED, That the American Fisheries Society favor legislation by Congress to provide for the regulation of this offshore fishery, and to provide for thorough and continued investigations to determine when depletion is threatened and what measures need be taken to prevent such depletion.

Cooperation with State and Federal Agencies

Recognition by the American Fisheries Society should be given to the advancement in scientific research and investigation by the staffs of both state and federal agencies in the discovery and the application of newly established and proven methods for increasing the production of commercial and game food fishes.

In this connection it is worthy of note that during the past fiscal year the increase in the number of both commercial and game food fishes propagated and planted by the U. S. Bureau of Fisheries approximates one billion over any previous year in the history of the Bureau.

It is evident that these advances in all phases of fisheries operations have been brought about in large measure through a wholesome coordination and cooperation on the part of state and federal agencies as proposed by the Commissioner of the Bureau of Fisheries at a conference with state agencies in 1934.

THEREFORE, BE IT RESOLVED, That the American Fisheries Society in its 66th Annual Convention assembled express its pleasure and satisfaction in respect of the forward strides which are being made by both state and federal agencies in their cooperation and in the application of proven scientific methods in fish culture, resulting in a progressive increase in the production of commercial and game food fishes.

BE IT FURTHER RESOLVED, That the American Fisheries Society, and especially those members who are not directly connected with either state or federal agencies, assure those agencies of its desire to cooperate with them at all times in advancement along right lines to the end that a maximum of results may be obtained.

Stream and Lake Pollution

BE IT RESOLVED, By the American Fisheries Society in convention assembled at Grand Rapids, Michigan, September 4, 1936, that this Society endorse and urge the passage of federal legislation at the next session of Congress to correct and remove stream and lake pollution in the waters of the United States, and that said legislation embody the following principles:

(1) That it establish a clearing-house for information on water pollution problems open to all concerned;

(2) That it provide for utilization of existing governmental agencies;

(3) That it insure proper representation of all major interests concerned in stream pollution, both in the consideration of the problems and in the administration of the legislation;

(4) That it provide means of financing municipal sewage and trade waste disposal plants by loan of federal funds, and in the case of municipalities to grant part of the cost of such disposal plants; and

(5) That it give power to the pollution abatement agency to compel polluters of natural and impounded waters, who will not voluntarily cooperate, to comply with the provisions of the pollution abatement agency.

BE IT FURTHER RESOLVED, That legislation not embodying these principles would be of little value to fisheries interests.

Appreciation of Courtesies

WHEREAS, The American Fisheries Society in its visit to Michigan has been graciously entertained; and

WHEREAS, The members of the Society and their wives have been given every possible courtesy and every possible assistance that might add to their comfort; and

WHEREAS, The Society is desirous of expressing its appreciation;

THEREFORE, BE IT RESOLVED, That this Society extend its appreciation and thanks to the Michigan Department of Conservation, the management of the Pantlind Hotel, the Press, Radio Station WOOD and WASH, the Kent Garden Club, and to all other organizations and individuals participating in the planning and carrying out of this the Sixty-Sixth Annual Meeting of this Society.

MR. QUINN: I move the adoption of the resolutions as read.

(The motion was seconded by Mr. LeCompte and carried unanimously).

SPECIAL COMMITTEE ON REVISION OF BY-LAWS

MR. DENMEAD: At Tulsa last year we were pressed for time; we made a great many changes in the constitution, and I suggested we adopt them without much discussion, because if they did not work we could change them. I am glad to say that the changes made at the last convention were very satisfactory and have worked well. There are, however, a few suggested changes, which I shall proceed to outline.

Article II, which deals with membership, now provides that any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting. It provides that the annual dues for state membership shall be $10 per year. It has been suggested that the constitution in this respect be amended so that it shall read:

> The annual dues for state membership shall be twenty dollars ($20.00) per year.

The effect of this change is to increase the annual dues for state memberships from $10 to $20 per year.

In the constitution as it stands, Article IV, Officers, it provides as follows:

> Only members in good standing who are in attendance or who have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee.

It is proposed to add to that section the following words:

> excepting the members of the Committee on Common and Scientific Names of Fishes.

The reason is that the committee does most of its work by correspondence and it is not necessary for these gentlemen to be in attendance.

Article IV provides also that the officers of the Association shall form an Executive Committee, with authority to decide the policies of the Society, and to transact such business of the Society as may be found necessary. It is now proposed to add to the duties the following:

> the Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings.

It is proposed also that it be provided that a majority of the Executive Committee shall constitute a quorum. The only thing that does is to make it clear how the officers shall fill vacancies, and to change the quorum of the Executive Committee from seven to a majority. That is necessary because we do not know how many we may have at these meetings, and the majority is six instead of seven.

There is at present a grammatical error in Article V. "Selected for election by the Nominating Committee." It is proposed that this be changed to read "selected by the Nominating Committee for election."

At the present time it is provided by Article II that twenty-five voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society. It may be difficult at Mexico City to get a quorum of twenty-five at the last hours of meeting, and the suggestion is that the quorum be reduced from twenty-five to twenty. This provision will then read:

> Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

I move the acceptance of these changes in the constitution. They have been very carefully considered and I am satisfied that they are for the benefit of the Society.

(The motion was seconded by Mr. Quinn and carried unanimously.)

COMMITTEE ON TIME AND PLACE

THE SECRETARY: The following report has been submitted by the Committee:

Your Committee, meeting jointly with the Time and Place Committee of the International Association of Game, Fish and Conservation Commissioners, considered invitations extended by the Department of Game and Fish, Province of Ontario, Canada; the Republic of Mexico, and many States of the Union.

Your Committee considered also the location of meetings in the past and the policies which appear to have determined the selection of those locations, generally on the basis of rotation from East to West, North to South within the States, and with occasional meetings in the Canadian Provinces. It appears that locations of meetings have been influenced also by a desire of the members thus to recognize conspicuous services rendered in the field of wildlife conservation and scientific research, and occasionally by a desire to help some weaker state which showed promise of establishing a sound program of fish and game administration.

In view of the fact that the Republic of Mexico has recently signed a treaty with the United States for the protection of migratory birds, and the fact that the proper conservation of many important marine fisheries, particularly on the Pacific Coast, is dependent upon international good will and cooperation, especially between Mexico, the United States and Canada, your Committee believes that this Society can render a valuable service to the cause of wildlife conservation, as well as to its own broad interests, by making the friendly gesture of holding its next meeting in Mexico in recognition of the encouraging progress which has been made there.

Your Committee therefore recommends that the invitation extended by the President of the Republic of Mexico be accepted, and that the next meeting of this Society be held in Mexico City, August 23 to 25, 1937.

Since the Chairman of the Committee is not here, I move the adoption of the Report of the Committee.

MR. QUINN: I second the motion.

(The motion was carried unanimously.)

COMMITTEE ON NOMINATIONS

MR. WESTERMAN: Your Nominating Committee, in submitting its recommendations for officers and committee members, has given careful consideration to not

only the several general groups of the Society such as scientists, executives, and fish culturists, but also to give recognition to the section of North America where the next meeting is to convene.

Some of the present officers have requested that they be relieved from their duties. Your committee thinks it is inadvisable to recommend a change in these officers except for the most compelling reasons. It did agree upon a compromise in one of the offices (Librarian) as a small measure of tribute to the man who has so faithfully carried out his duties, and in recognition of the service which his state renders to the Society.

Your committee therefore submits for your consideration, the following names for officers, vice-presidents of divisions, and committee members for the ensuing year, and recommends the election of same:

Officers

President—A. G. Huntsman, Toronto, Canada
1st Vice-President—I. T. Quinn, Montgomery, Alabama.
2nd Vice-President—Fred J. Foster, Seattle, Washington.
Secretary-Treasurer—Seth Gordon, Harrisburg, Pennsylvania.
Librarian—Kenneth E. Cobb, Windsor Locks, Connecticut.

Vice-Presidents of Divisions

Fish Culture—A. D. Aldrich, Tulsa, Oklahoma.
Aquatic Biology and Physics—M. M. Ellis, Columbia, Missouri.
Commercial Fishing—M. C. James, Washington, D. C.
Protection and Legislation—Wm. J. Tucker, Austin, Texas.
Angling—Kenneth A. Reid, Connellsville, Pennsylvania.

Committee on Foreign Relations

W. F. Thompson, *Chairman*, Seattle, Washington.
David L. Belding, Boston, Massachusetts.
Herbert C. Davis, Sacramento, California.
H. H. MacKay, Toronto, Canada.
James A. Rodd, Ottawa, Canada.
Fred A. Westerman, Lansing, Michigan.
Senor Juan Zinser, Mexico City, Mexico.

Committee on Common and Scientific Names of Fishes

Carl L. Hubbs, *Chairman*, Ann Arbor, Michigan.
Walter H. Chute, Chicago, Illinois.
Wm. J. K. Harkness, Toronto, Canada.
Samuel F. Hildebrand, Washington, D. C.
A. H. Leim, St. Andrews, N. B., Canada.
John O. Snyder, Stanford University, California.

MR. LECOMPTE: I move the adoption of the report, and that the secretary be authorized to cast a ballot for the nominees recommended by the committee.

(The motion was seconded and agreed to.)

THE SECRETARY: I beg to report that the secretary has cast one ballot for the entire group of nominees.

THE PRESIDENT: Then they are declared elected unanimously.

I will appoint a committee consisting of Mr. Quinn of Alabama, Mr. McCall of Arkansas, and Mr. Rodd of Canada to escort the newly elected president to the Chair.

(The President elect was escorted to the Chair, amid applause.)

THE RETIRING PRESIDENT: Members of the Society, it is a great pleasure to me to introduce to you our new president, Dr. Huntsman of Canada. I think the Society acted very wisely in the selection of Dr. Huntsman, who is known not only in North America but throughout all of Europe as a leading man in scientific and fisheries work.

DR. HUNTSMAN: These occasions are difficult moments. Naturally I feel very much honored at this expression of appreciation of the part that Canada has played in reaching the objectives the Society has before it; because in spite of the very kind remarks of your chairman I take my selection to this position not as a personal thing but as a recognition of what Canada has been trying to do, and I am sure it will be appreciated by those with whom I am associated in fisheries work in Canada. It is appreciated all the more when we remember that Canada is a very small country as compared with its neighbor to the south, from the standpoint not only of population but of accomplishments in these other fields.

At this time I should like to take just a few minutes, having thanked you for the honor you have done Canada and myself, in making reference to the work for the next year in which I shall have certain responsibilities. Next year we shall be meeting in a new country, and that prospect has been received variously. When the announcement was made that the two associations would meet in Mexico in 1937, some expressed the opinion, though not in these terms, that it was sure to be a fizzle, that very few will go; and undoubtedly the success of the Society depends largely upon the annual meeting and the annual meeting depends wholly upon the personnel of that meeting. It is important, therefore, that you have in attendance a large number of persons with knowledge of the various phases of the fisheries and with the desire to exchange notes as to their experiences. That is what constitutes a good meeting, and that is what chiefly constitutes the success of the Society for the year.

Now, what are the possibilities for this coming year? I am not as pessimistic as some who have spoken to me; in fact, after talking with a certain number of members of the Society I am feeling quite optimistic. It is difficult to tell in what way the new situation will be met; a novel situation is something the results of which you cannot properly predict. Will members of the Society be deterred from attending the meeting because of the long distances they may have to travel, or will they be attracted by the possibility of adding something really new to the store of their experiences?

I am rather inclined to believe that in very many cases the latter may prevail, and that those who are nearly as far from Mexico City as I am myself, and as the majority of our people are in Canada, will be prepared to travel that distance to have the very novel experience of meeting in Mexico. From the fisheries standpoint we will meet people very different from ourselves, people who are facing problems very different from those with which we are familiar. Possibly those in the southwestern part of the United States will not find the conditions too dissimilar from what they have been accustomed to for a long time, but there is no doubt that the farther away members of the Society are removed from Mexico the more likely will they be to find something novel when they go there, and it so happens that the greater part of the membership of the Society is very remote indeed from that country. Will they, then, respond to that attraction and take this opportunity, possibly the only one in a lifetime, of getting a really new experience? The younger members may feel they are getting enough new experience every day; the older members may feel that there is no particularly new experience to come to them—that tends to be the difference between youth and old age. But I am inclined to believe that both old and young will be amply repaid for any lengthy trip they may have to take to go to Mexico—that is, putting it from the purely selfish standpoint. I hope, on the other hand, we will respond to the appeal that Mexico has made that the Society give it some idea of what this organization means and what the direct or indirect accomplishments of the Society may signify for Mexico, what the results of our study, re-

search and experimentation may mean if followed in that country. I think we have a real opportunity there. We cannot tell what this meeting will be, it presents so many possibilities; but I am very hopeful.

While there may be a tendency to regard large attendance as a criterion of success at a meeting of this kind, I would point out that a good attendance is better than a large attendance, and I hope all those states who are active in presenting ideas will make it a point to be in Mexico City next year. Some of the relatively retiring members are quite active in that respect; they will not say much, but when they do speak they contribute vastly to the success of the work of the Society. So I do not lay emphasis only on the attendance of those who are apt to be on their feet frequently; we value also the attendance of those who do a great deal of thinking but perhaps do not so often express themselves.

I am wondering whether the occasion of this meeting in Mexico City might not be one for special effort on the part of our membership on the Pacific coast. I would like our Pacific coast members to take that into consideration from the point of view of trying to get those in fisheries work up and down the Pacific coast to make it a point to be there. Indeed it might be not a bad idea to make it more or less of a Pacific coast meeting so far as fisheries people from that part of the country are able to swamp those who come from the East—and let it be a struggle.

That brings up a point in connection with the American Fisheries Society I have not heard discussed, although perhaps it has been. The American Fisheries Society started in the East, and part of Canada was very shortly associated with it; in fact that part of Canada is more closely associated with the adjacent part of the United States in the work that has been done in and through the Society than the Pacific coast area of either country. There is a tendency for East and West to separate, western Canada and the United States coming together with the movement up and down the coast, and similarly in the east. So that speaking from the standpoint of an organization such as ours we tend to have in Canada and the United States an Atlantic coast area and a Pacific coast area, with perhaps on the whole an interior tending to go with the Atlantic coast because of the mountain barrier between the central part of the continent and the extreme west. This emphasizes the fact that national barriers in the work we seek to accomplish in our organization mean relatively little, and we are perhaps exemplifying that in our decision to go down to Mexico next year.

I have some diffidence in accepting an office such as this because of one difficulty we will have, namely, that of language; it almost seems as if we should have had a personnel in charge of the Society that would be able to understand not only English but Spanish as well. But perhaps that is too much to expect, and the conference next year may have to be a strictly English meeting. It is to be hoped, however, that the Mexicans will have some opportunity to express themselves in their own language, with interpretation into English. We will have difficulties of that kind, but they will have to be met by those in charge; indeed, they may only add to the interest and amusement of those who attend. I hope we shall have success during this coming year.

THE PRESIDENT: Thank you, Dr. Huntsman.

THE SECRETARY: It has been agreed by Dr. Huntsman, the incoming president that since the Executive Committee has ruled that next year titles must be submitted at least thirty days ahead, along with that notice of the title shall come a brief abstract, not to exceed one double-space type-written page, setting forth the purpose and scope of the paper and its conclusions, so that the committee will know exactly what the paper covers.

It is also suggested—this, by the way, is Dr. Huntsman's idea, and I thoroughly concur in it—that in the future in sending out our notices with respect to the meetings and suggestions for the preparation of papers we ought to ask the authors to give such a summary or *brief statement right at the beginning.* The

point is that instead of following the procedure that has been followed in the past, that of putting the conclusions at the end, you really start with your conclusions and then give the findings on which they are based, so that any member can read the first page of the paper and see what it is all about. If he wants to examine the details, he can do so; if not he does not have to wade through the whole paper before he finds the conclusion.

MR. REID (Pennsylvania): Do I understand, then, that those who submit papers next year are requested to furnish a supplementary one page double-space typewritten abstract of approximately 150 words?

THE SECRETARY: A maximum of two hundred and fifty to three hundred words.

MR. REID: Why not just publish that as a preface?

THE SECRETARY: That is what it will be, and then if the author wishes to do so he can use that same statement at the beginning of his paper for the record.

THE PRESIDENT: I want to thank the members of the Society for their co-operation during the past year and the help they have given me in making this meeting the success that it has been. Particularly has the local Committee looked after every detail and made every effort to make us comfortable and happy while we were here.

May I say that in ensuing years the Bureau of Fisheries will be just as much interested in the success of the American Fisheries Society as we have been this year. Again I wish to thank Mr. Gordon, Mr. Denmead and Dr. Higgins for taking off my shoulders the burden of arranging this program.

(The meeting adjourned.)

In Memoriam

John P. Babcock, Canada
Eugene Catte, Kansas
Charles A. Coolidge, Massachusetts
T. L. Hankinson, Michigan
Alexander Macdonald, New York
W. W. Near, Canada
Henry O'Malley, Washington
William J. Sanson, Canada
Eben P. Thompson, Massachusetts
Bryant Walker, Michigan

PART II
PAPERS AND DISCUSSIONS

FISH MANAGEMENT: LOOKING FORWARD

CARL L. HUBBS

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Mich.

The need for thorough, soundly planned and adequately administered fish management is coming to be generally appreciated. I have thought it wise at this time to consider the future development of fresh-water fish management in America. We should now make an effort to foresee this future: to judge the need for and the promise of fish management as the means of maintaining and upbuilding the future game fish supply; to appreciate the forces against which management must struggle, or with which it may compromise, in order to grow and be of really effective service; to estimate the amount of growth which the field may make; to plan for the adequate training of a sufficient number of specialists; finally, to attempt some understanding of the administrative problems that will arise as the field of fish management expands.

It is being realized that the well-meaning efforts of the past have been to a large degree haphazard, incomplete, imperfect, uncoordinated, nontechnical and untested. This or that restrictive regulation has been proposed, on the basis of some fish culturist's intuition or some politician's whim or expediency; and these regulations have been more or less thoroughly enforced, and changed from time to time in an effort to meet public approval, with scarcely an attempt having been made to determine their real effects. Separate regulations for different bodies of water have usually not been considered although these are the production units and vary in their need for protection. Exotic species have been introduced, without investigation or mature thought, with good results or bad, depending largely upon luck. Artificial propagation has been resorted to, using methods devised by the trials and errors of early enthusiasts, and then followed, rule of thumb fashion, by untrained, underpaid superintendents. Too little effort has been made to test and improve the varied fish-cultural practices, from egg-taking to distribution. The artificially reared fry or fingerlings have been scattered more in line with political pressure than with the needs of the waters stocked; waters wholly unfit for a given species have been wastefully planted; others have been overstocked until the fish have become dwarfed; a thousand fingerlings have been enthusiastically put in a lake containing a million naturally reared fingerlings of the same species; lakes and streams sorely in need of stocking have been neglected—all without adequate surveys, plans or administration. Almost no adequate tests have been made of the results of the artificial propagation of any species, either in specific waters or in general. Lake and stream surveys have been intermittently under-

taken, too often by wholly untrained workers, or by good biologists without specific fisheries training, and often less interested in developing practical fish management plans than in non-practical research of personal interest. Quite as often the fishery officials, through a lack of understanding, or of funds, or of effective administrative machinery or personnel, have received, filed and forgotten the technical reports of their fishery investigators. As a rule, neither the fish-culturists propagating fish, nor the technicians conducting surveys, have given any considerable thought to the improvement of lakes and streams, to make them produce a large fish crop. Though stream and lake improvement has become popular and extensively practiced, very little attention is devoted to testing the benefits resulting from this new line of fisheries work. Even in the most progressive states, fish management has approached efficiency only in certain limited phases, or in a few, small regions. And the Bureau of Fisheries is not so far in the lead as it should be. We all remain in need of thorough, sound and adequate fish management.

Despite many serious mistakes and an enormous amount of wasted effort, every phase of fish management has at times and at places succeeded in increasing the production of game fish. Some restrictive legislation has proved indispensable. Introduced species are the chief food and game fishes of certain waters, witness the striped bass, black bass, catfishes and shad in the warmer fresh waters of central California, or the brook, brown and rainbow trout in most of the main streams of Michigan. Surveys have disclosed many previously planted waters as unfit for game fish, and some unplanted waters where fishing has been greatly improved by stocking, following the survey recommendations. Spectacular instances of success have been attained by the improvement of some streams and lakes, for instances in making good fishing water out of portions of streams that were formerly fishless deserts. It is reasonable to predict that organized and adequate fish management will increase the success of future efforts to increase the game fish supply.

The extension and improvement of fish management will be attained, we may feel sure, only after a constant struggle. As in all progress, chief opposition will come from the forces of conservatism: from men who are satisfied to live their fathers' lives; from officials and politicians who (often with justice) distrust all that smirches of the technical, and are unwilling or unable to finance the enlargement and improvement of their fish divisions that is necessary, if real fish management is to be realized, and from the incumbent fishery officials who fear they may lose their positions if their divisions are reorganized.

Opposition to management is already developing within the technical field. I refer to the growing struggle between the philosophies of management and of preservation, between the utilizers and the preservers of nature. The ultra-preservationists, as I call them, wish to prevent the sordid hand of man from further despoiling natural conditions;

their interest in the natural relations between all forms of life is incompatible with fish management, which strives to modify the natural populations and the environmental conditions so that a few species desired by the sportsman will dominate the waters. There are signs to indicate that this struggle between two schools of naturalists will become increasingly intense and at times bitter. The preservationists should realize that fish management, with game management, is but the extension of agriculture, the cropping of wildlife; that natural conditions in our waters are already almost universally modified by the introduction of exotic species, by the clearing of the adjacent land, by the removal of cover within the water, by pollution, by alternate floods and low water and particularly by the silting over of the original stream beds as a result of erosion; finally that fish management, particularly stream and lake improvement, very often aims to restore natural conditions which have already been destroyed by man.

There is so much logic and justice in the views of the preservationists, however, that some compromise should be sought. Certain relatively unspoiled areas should be set aside as samples of primeval nature, underwater as well as above. It is much to be regretted that the National Park officials in preserving nature in the Parks have until very recently forgotten that nature does not stop at the water surface: while preventing the hunting and trapping of animals and the cutting of trees or flowers, they have urged fishing and have greatly modified the underwater nature of the Parks by introducing exotic species. In lake and stream improvement work, efforts should be made to restore natural conditions and to make constructions that seem natural. Waters inhabited by rare or local kinds of fish that are or would be in danger of extermination, should not be stocked with exotic species.

Fish predators within reason should be tolerated, giving due regard to the value or interest of the predators to others, or should be decreased in fishing waters by such means as frightening rather than killing, or by modifying conditions to make them unfavorable to predation (for instance, by increasing the vegetational canopy over trout streams to decrease predation by herons and kingfishers). There are those who would rather hear a kingfisher rattle his way down a stream than to catch a trout; their desires and rights should be respected. The development of fish management, I believe, will be hastened and rendered more sound, if fish managers compromise and counsel with the preservationists.

Opposition to effective fish management is also being offered by other utilizers, as contrasted with the preservers, of nature. The towns and industries that utilize streams to carry off their wastes are foremost among the other utilizers of nature. We need not argue here that pollution must be controlled, to maintain or restore the fish supply of our streams and lakes. The removal of harmful pollution and the treatment of sewage that can be rendered harmless or even beneficial to fish life

by suitable treatment, should constitute a main objective of fish management. Preventing the silting over of stream and lake bottoms, and correcting the effects of silting will probably become an even more vital aspect of future fish management.

Those who remove cover from the bottoms and shores of our streams and lakes are among the outstanding opponents of fish management. The time may be passing, we hope, when lumber companies may go down a stream removing all cover to facilitate the driving of logs. But cottagers will continue to make bathtubs of their lakes, and complain about how few fish remain (seeking some wisp of cover). Army engineers will continue to make putrid settling basins in our great rivers, in their nine-foot channel programs. Agricultural interests and health authorities will continue to drain rich ponds, and lateral marshes which produce fish food and provide fish nurseries. Relief agencies may continue to make straight, shadeless, pool-less, coverless, fishless ditches out of beautiful streams, in the name of flood control or of agriculture, or merely because cutting down 300-year old sycamores and carting off the islands and bends of a stream in wheel-barrows is an easy way to make use of superfluous man power.

Fish management will meet these and no doubt other forces of opposition. It will be well to prepare for a ceaseless struggle with the opposing interests; to fight when victory may be expected and justified; to compromise when necessary, or when desirable from the broad viewpoint of water utilization. (But when the government sets up Water Utilization boards not including a fish manager, let us be heard).

Despite all opposition, technical fish management will, I feel sure, develop enormously during the coming decade. The movement is already well under way. State after state is expanding its fishery program, and is making an effort to place fish conservation on a technical basis. Conservation authorities are coming to appreciate the need for and the value of a technical staff. There is developing a distinct field of fish management in which young men may specialize, leading to careers of service in the conservation and upbuilding of the game fish supply. There is need, and the demand I feel sure will arise for a many-fold increase in the now hopelessly inadequate number of fish technicians.

The success to be attained in fish management during the next decade or two will depend in large degree upon the number of men whom we train for this work and for the accompanying fishery research, and on the thoroughness with which we train them. Success in fish management will also be related to the development and testing of management methods, by the present nucleus of technicians and by their students. A large responsibility, therefore, lies on those who will train the freshwater fish technicians of the future and will develop the field. The state departments who will benefit from the adequate training of fish managers should share this responsibility, in part by providing fellowships and student assistantships to aid young men of promise in obtaining a

fisheries training. It is hoped that the American Wildlife Institute will also support the advanced training of a considerable number of future leaders in fish management.

Administration problems will arise, of course, as fish management becomes at once more intensive and more extensive. It would be foolhardy to predict just how these problems will be solved, for to do so one would need predict the future of our political and social system. We can say with assurance, however, that the present fish administration for any inland state is wholly inadequate in staff, with respect to numbers and training. Furthermore, the usual theory of organization and the method of administration are unsuited to really thorough fish management. Fish management is aquatic farming; applied by the state, it is the cultivation and harvesting of the wild fish crop. It is as senseless to try to really manage the fish in all the waters of a state by the usual state fish division organization as it would be to try to operate all the farms of the state from the state capitol, using a few officials and perhaps one or a very few technical experts. Eventually, I venture to predict, we will need and will use a trained fish technician in each of the many fishing districts of such a state as Michigan. This man would keep the local conditions under constant observation, determining the special needs of each body of water in the way of regulations, stocking and improvement; then meeting these needs with appropriate action. The organization would be very costly, but the increased crop should well justify the expense. Until some such system is inaugurated, we can hardly compare fish management to farming. And until that time, we can not expect to harvest even an approach to the maximum fish crop which our waters are capable of yielding.

OBSERVATIONS ON NATURAL VERSUS ARTIFICIAL PROPAGATION OF COMMERCIAL SPECIES OF FISH IN THE GREAT LAKES REGION

LESTER SMITH

Commercial Fisherman, Member Fishery Advisory Committee, Port Washington, Wisconsin

The practice of artificial propagation of commercial fish of the Great Lakes has long been the subject of considerable argument, especially among commercial fishermen. Those fishermen who favor artificial propagation base their argument on the theory that nature is often wasteful in her efforts at reproduction, while those who oppose hatchery methods deny this and claim that man only is wasteful. Unfortunately there is no yardstick by which one can check accurately the claims of either side. The Great Lakes are so large that fish, in their migrations, show up unexpectedly in large schools and sometimes apparently become very scarce, thereby creating mistaken impressions as to their actual numbers in the lake. In addition, our lack of knowledge of the habits of the fish, the increase or decrease of natural enemies, the variation of food supply, lack of reliable statistics, difference in the amount and kind of gear used by fishermen, and the conflicting laws of the Lake States, all serve to complicate the problem. The question, however, is an important one since it not only has an immediate application to a basic industry but is actually involved in the problem of preserving a valuable food supply for future generations.

Interest in artificial propagation of commercial fish such as lake trout, whitefish, and yellow pike-perch naturally grew as the depletion of these fish became apparent. It is reasonable to assume that few commercial fishermen were interested in applying hatchery methods in 1880, when the lakes teemed with fish life. Fishermen then could catch all the fish they were able to handle or sell with gear which today would be obsolete. As the country became settled, however, the demand for fish increased, and the row boat and sail boat, equipped with hand-made nets, gave way to the steam tug and later the gasoline boat, equipped with machine-made netting. Improved net-pulling machinery more than doubled the amount of gear that was handled by a crew. In addition, the modern oil engine which came into use about 1916 made it possible for commercial fishermen to reach every fishing ground on the Great Lakes. With each improvement it was noted that the total production was maintained, and in some cases actually increased, but slowly, as time went on, the average catch per unit of gear decreased. In order to offset this steadily declining production, fishermen set more nets and

began reducing the size of mesh, often with the approval of the state governments. The reduction in the size of the mesh resulted in the capture of more fish, although they averaged smaller in size and many of them were immature.

Although artificial propagation of commercial fish of the Great Lakes was practiced as early as 1875, it was not until about 1900 that the problem of maintaining the fisheries was seriously attacked from this angle. At that time zealous fish culturists entered the scene, confidently asserting that they could maintain the abundance of fish in the lake despite the increased fishing intensity. Enthusiasm in favor of artificial propagation was general and hatcheries, both state and federal, were established at strategic points around the lakes. The first problem was to get the eggs for the hatcheries. Because the various Lake States were then, as at present, not equipped financially or otherwise to get these eggs, the state departments had to depend on private enterprise and as a natural sequence the so-called "permit system" was established.

Briefly, the "permit system" is as follows. The State grants a special written permit during the height of the spawning season of the fish to certain fishermen directing them to set their nets for the purpose of obtaining and fertilizing the eggs which are brought ashore and turned over to the hatcheries for incubation. In remuneration for labor and for the use of their boats and gear, the fishermen are allowed to keep and market the fish. The spawn-fishing period covers about two weeks and the gear most generally used is gill nets. Most regulations require that test nets be set to determine the ripeness of the fish before permits are issued.

As might be expected, the inauguration of this permit system brought with it many abuses, for some fishermen who received permits regarded this privilege only as an opportunity for personal gain, "fishing for fish instead of for spawn" as one fisherman put it. This situation was aggravated by the fact that at first there was little or no supervision on the part of the State, probably because the work was dominated by overoptimistic fish culturists who were more interested in the eggs than in the methods of collection. According to the rules, only fishermen who had large-mesh nets and were located near the best spawning grounds were given permits. Because not all fishermen could qualify according to these regulations, and because of the fact that fishing under permit was often profitable, many of the less fortunate fishermen became disgruntled. In addition, there were other fishermen who sincerely declared that natural spawning was more efficient than artificial propagation and so it was not surprising that opposition to commercial fish hatcheries began to develop.

The case of those commercial fishermen who are against hatchery methods is largely economic and can be set down as follows:

Hatcheries, they claim, have failed in results. Since the time hatcheries have been established there has been a steady decline in the production of the species artificially propagated, especially lake trout and

whitefish, while at the same time other fish, such as herring and smelt, have maintained themselves by natural propagation.

Critics claim that artificial methods as practiced have been wasteful. The arguments supporting this statement may be classified under two heads:

I. Objections based on uncontrollable factors.
   1. It is stated that because of the large quantities of fish caught during the spawning season and because of the poorer quality of the fish,* markets become glutted making it necessary to freeze a large portion of the catch. It is claimed that this frozen stock, when put on the market later, has a depressing effect on price and demand.
   2. Bad weather conditions during the spawning season make spawn-fishing hazardous and often destroy much gear.
   3. Fishing under permit from the State naturally involves the killing of the adult stock from which the spawn is taken, thereby removing the possibility that these parent fish can spawn again.

II. Objections based on controllable factors.
   1. Inefficient and disinterested help on tugs and in hatcheries has often resulted in unnecessary losses of eggs when spawning the fish and when hatching the eggs.
   2. Permits issued too early allowed the killing of too many males and too many green females.
   3. Some fishermen are permitted to fish too small a mesh that results in the catching of sexually immature fish.
   4. Unexpected hazards during incubation, such as harmful chemicals in the water, sudden changes in water temperature, and stoppage of water supply may have serious results during hatchery operations.

In fairness to the various state fishery departments, it must be said that at present the mistakes in hatchery methods based on the human element have been either largely overcome or by constant care are being steadily avoided to a marked degree. This leaves only the problem of the three objections based on uncontrollable factors, namely, glutted markets, production hazards, and destruction of spawning fish. Of these the first two are usually, but not always, present but the third, under the present system, is inevitable. Unlike the salmon, lake fish do not die naturally after spawning.

Fishermen who are opposed to hatcheries often make the general statement that only natural propagation will bring back the industry, al-

* No positive proof is available that spawning fish are less desirable than the non-spawning for food, but it must be said that there are grounds for believing that some physiological change occurs in the spawning fish. Restaurant chefs who broil fish claim that lake trout caught during the spawning season will not "brown."

though no definite proof is advanced to back up this claim. One Wisconsin group even goes so far as to say that size limits and limits on mesh and type of gear are unnecessary at any time, so long as fish have strictly closed seasons during which they can spawn naturally. One would not doubt their sincerity were it not for the fact that these same fishermen have a record for opposing many conservative plans for mesh and size limits designed to preserve the fish supply.

In contradiction to the above assertions, however, those commercial fishermen who favor artificial propagation contend that the future of the fishing industry as a whole depends on the fish hatcheries. They base their assertion on the following claims:

I. Artificial propagation has been a bulwark against depletion of the more valuable fish of the Great Lakes because:

1. The percentage of fertilization of eggs is greater with artificial propagation than with natural propagation. This is generally conceded to be true by most fishermen. Some fishermen have collected eggs of which 97% were fertile. In general the percentage of fertilization averages more than 60 in the lake trout. Wisconsin claims a 63% hatch in its lake trout eggs. Saskatchewan reports its 1935 hatch of lake trout at 80% and 96.6%. The fact that adult fish are killed in order to get the eggs may be ignored in view of the great fecundity of the females and the much higher percentage of fertilization by artificial hatching.
2. The mortality of eggs on the bottom of the lake is largely due to infertility of naturally spawned eggs, moving debris during storms, and bacterial attack.
3. The mortality of the fertilized eggs due to natural enemies is prevented by artificial propagation. Lake trout and whitefish eggs have been found repeatedly in the stomachs of burbot, pilot fish, and baby lake trout after the spawning season. It is a common sight to see a small school of yellow perch follow a spawning mullet and eat the eggs as fast as they exude from the body. Without any doubt, such fish as lake trout, whitefish, and yellow pike-perch are subject to the same attack when spawning. The stomach of one burbot caught in November, 1936, was found to contain no less than 1,653 lake trout eggs. None of these eggs were found to be fertile. We know definitely that lawyers or burbot congregate regularly every year on the spawning grounds of lake trout. Fishermen generally concede, without argument, that the mortality of the fry, whether naturally or artificially hatched, is less than that of the eggs.

II. Natural, not artificial, propagation has failed.

> In considering the matter as a whole, the part played by artificial propagation has been negligible when compared with natural propagation under average conditions. With very few exceptions, the most intensive applications of hatchery methods on any one of the Great Lakes has resulted in not more than 5% of the occupied spawning-areas being touched with nets, and certainly less than 10% of all the eggs produced in the lakes in any one season have been subjected to artificial hatching. Therefore, if natural spawning is the salvation of the fishing industry, it is plain that we can still depend on natural methods to the extent of at least 90%. Inasmuch as this 90% has failed to maintain the fishing industry, certainly there is no hope in 100% natural propagation under the same conditions. Nearly every fisherman will admit that the chubs of Lake Michigan have been depleted, yet these fish have never been propagated in hatcheries except on rare occasions.

Naturally, one might be interested in the stand of the various Lake States on this subject. In no case has any State taken a definite stand against artificial propagation of commercial species of fish. Some have modified or abolished the permit system, but none have closed the hatcheries. Canadian provinces are especially enthusiastic in favor of fish culture and excellent results are reported, even as far north as Lesser Slave Lake. A poll of the Great Lakes fishermen taken several years ago on the question, "Are hatcheries beneficial to commercial fishing," showed that 92% of the Canadian fishermen and 68% of the United States fishermen favored artificial propagation.

Most fishermen, however, will admit that there is room for improvement in the present system under which hatcheries are conducted. Greater efficiency can be obtained by making several changes as follows:

First—The number of gangs of gill nets allowed in the water for each boat while fishing for the hatcheries should not exceed two, and with a limit of 22,000 feet per gang. This practically eliminates the possibility of taking dead fish.

Second—A minimum gill-net mesh of five inches should be used for spawn-fishing for lake trout, whitefish, and yellow pike-perch, with one-third of the nets made of five-inch mesh and two-thirds of the nets made of six-inch mesh. The reason for this regulation is three-fold: first, to assure the taking of mature fish only, second, to increase the efficiency of the gill nets since female fish are generally larger than the males and require a larger mesh for their capture (one male fish will produce enough sperm to fertilize the eggs of many females), and third, to assure the capture of more individuals of the older age—groups which have a comparatively lesser life expectancy. Every third net set for

spawning fish should be of the smaller mesh so as to provide a ready supply of males for fertilization.

Third—Each State equipped for hatchery work should operate one experimental tug during the spawning season each year for a period of at least five years for the purpose of determining the most efficient methods for artificial propagation of the various kinds of commercial fish and to determine whether the parent fish can be saved after being spawned. This tug should be properly equipped with necessary gear and manned by a crew of interested, experienced fishermen. Whenever practical, all fish which are uninjured after being spawned should be tagged and released and a complete record made of each fish liberated.

Fourth—All commercial fishermen should be taught the great possibilities of artificial propagation even when fish are apparently plentiful. Hatchery methods should not be depended on only as a last resort when the fish supply is reduced to the point of exhaustion. The fisherman who artificially fertilizes a quantity of ripe eggs and deposits them back into the lake is doing a good deed.

Fifth—A uniform hatchery program for all States bordering on the same lake is desirable, thereby making it possible to compute results more accurately for each lake.

Sixth—More scientific data on the life-history of the species to be propagated are desirable. For instance, we know very little about the following varieties of lake trout (1) the so-called "buckskin trout," small in size, that migrates southward along the west shore of Lake Huron every fall, none of which have been found with spawn; (2) the fat ciscowet trout of Lake Superior which spawns in sixty to eighty fathoms of water; and (3) that interesting family of small, red-meated trout which spawns in northern Green Bay on different grounds than do the common lake trout and about ten days later.

Seventh—Except under very special conditions, all plantings of fry of commercial species of fish should be made in the waters from which the eggs were taken.

Eighth—Laws should be passed and enforced to protect as far as possible the young fish from destruction by nets before reaching maturity. The effectiveness of artificial propagation is sadly handicapped when, as in the case of Wisconsin, baby lake trout of 12 inches and baby whitefish of 13 inches are still considered lawful catch.

In addition to the above suggestions, it is recommended that the dates of the present closed seasons be given further consideration. In most cases the dates should be advanced from three to seven days. A fish going to the breeding grounds to spawn is worth more to the State than one coming from the grounds after spawning. Any change in the dates of the closed season, however, should not affect the dates of the period during which the fishermen operate under special permits to collect eggs. These operations should be carried on only during the height of the spawning season.

Most critics are inclined to regard the value of hatcheries that propagate commercial species of fish solely on the basis of actual physical results. The success or failure of artificial propagation cannot be judged alone on the basis of how many pounds of fish commercial fishermen produce. Other conditions must be considered which have a definite bearing on production. Fishermen can increase production by reducing the size of the mesh in nets, by fishing more nets, or by fishing with more efficient gear. The intensity of fishing is, therefore, an all-important factor. Even though we double the present output of our fish hatcheries, we will not reach our objective if we continue to legalize the sale of immature fish. Hatcheries that propagate species of fish are doing splendid work in the face of great handicaps. To abandon artificial propagation under the present conditions would be disastrous. Should this be done, drastic curtailment of all present commercial fishing operations would immediately be necessary in order to preserve our more important species.

To summarize, the basic reason for artificial propagation of commercial species of fish in the Great Lakes area is to prevent depletion and to rehabilitate the fisheries. The extreme stand of the over-enthusiastic pioneer fish culturists who resolutely predicted success by the use of large figures is matched today by a group of commercial fishermen and others who go to the opposite extreme and blame the hatcheries alone for the present scarcity of fish. The present deplorable condition of the industry cannot be laid at the door of artificial propagation, while in the face of conflicting state laws our lakes are being looted by overfishing and fishing with destructive gear. Proper control of commercial fishing, plus continued operation of hatcheries and the improvement of hatchery methods, must go hand in hand if our Great Lakes are to regain any semblance of their former productivity.

Discussion

Mr. Lester Smith (Wisconsin): Mr. Chairman, my paper has to do with the question of natural as against artificial propagation of commercial species on the Great Lakes. Being a commercial fisherman myself, and having followed this occupation on all the Great Lakes except Lakes Erie and Ontario, I find that this question comes very close to my work. It is also a question which has divided commercial fishermen into two factions during the last thirty years or so, and its importance lies in the fact that it concerns a basic industry and has to do with the very question of maintaining the fish supply of the Great Lakes. (Reads paper.)

Mr. Smith: I was very much interested in Mr. Locke's reference to the possibility of fishing for lake trout along the Chicago waterfront; we all hope for the time when that can be done again as it was in former days, and if such a time does arrive, the commercial fishermen will also profit a great deal in their operations.

The President: Thank you, Mr. Smith. Is there any discussion?

Dr. T. H. Langlois (Ohio): Fish culturists and fisheries investigators have been working for a great many years in an attempt to improve the commercial fishery situation without making noteworthy progress, and I simply wish to comment that when the commercial fishermen themselves are sufficiently interested to study the problems and to join with and present a paper to a group like this, it is a very hopeful sign.

SOME FISHERY PROBLEMS IN IMPOUNDED WATERS

M. M. Ellis

In Charge, Interior Fisheries Investigations, U. S. Bureau of Fisheries, Columbia, Mo.

Introduction

The sensational catches of game and food fish which have been taken from certain artificial lakes as the Don Martin Reservoir in northern Mexico, Lake Murray in South Carolina, and the Lake of the Ozarks in Missouri, and the development of many large scale projects throughout the country for hydroelectric power, river navigation, irrigation and municipal water supplies have greatly increased the interest in the fisheries possibilities of impounded waters, during the past decade. More recently some states have erected recreational centers in areas not favored with natural lakes by damming small streams and by conserving run-off waters behind earthwork dams.

The fish yield (either real or fancied) of many impounded waters however has lead to the widespread belief among many laymen that the high productivity of certain masses of water can be duplicated in any other mass of water of the same volume, regardless of depth or exposure, i. e., there is a tendency on the part of enthusiastic promoters of impounded water projects to estimate the probable fish production on the basis of cubic yards of water and since fishermen's stories are proverbially "good," such estimates are often even better.

The over-estimation of fisheries possibilities in impounded waters with the subsequent and unfortunate disillusionment in part comes from the loose but general application of the name "lake" with all of its implied characteristics to all impounded waters, since many bodies of impounded waters can not be compared correctly with natural lakes, either in their biochemical and biophysical characteristics, or in their fisheries possibilities.

The careful investigations of many limnologists on natural lakes both in this country and Europe have shown that although all natural lakes are undergoing progressive changes independent of man's activities, these changes for the most part are so gradual and often extend over periods so long that the attendant disturbances of the fauna are slight through a span of years. In natural lakes which are reasonably free from modifying influences set up by man, there are also fairly regular series of cyclic changes associated with the season and other factors, to which changes the lake faunae have long ago become adapted, that is, undisturbed natural lakes present a reasonably stable, predictable and aged environment in which the adjusted aquatic faunae thrive year

after year after year, as in Quinault Lake (Washington) and Kamloops Lake (British Columbia).

The student of impounded waters on the other hand is impressed at the outset however that conditions in impounded waters often vary abruptly and over wide ranges; that no biological adjustment on the part of fishes and other aquatic species is possible to some of these changes; and, that the environment supplied by impounded waters is new and unstable as compared with that of natural lakes. In fact in many impounded waters changes of catastrophic magnitude as far as the aquatic organisms are concerned occur at irregular and unannounced intervals, and often with a frequency disastrous to the aquatic faunae.

Therefore, before an intelligent program for the utilization of any body of impounded water for fisheries projects can be established it is essential that the limitations and hazards of such waters in the locality where they are created, be defined, for generalities from natural lakes are not readily applicable to many impounded waters.

Field and analytical studies made by the Columbia (Missouri) Unit of the U. S. Bureau of Fisheries during the past four years on over thirty of the various impounded waters in North America and on over fifty natural lakes, show that in impounded waters as in natural lakes the biochemical and biophysical characteristics which determine productivity and around which fisheries problems center are determined largely by the inter-reaction of four factors, namely, the configuration of the basin in which the water is impounded, the age of the reservoir or artificial lake, the water supply to the impoundment, and the removal of water from the reservoir. However, the problems presented by these factors in impounded waters are often strikingly different from those in natural lakes.

Basin Configuration

The basins of most natural lakes are more or less bowl-shaped or at least have a central kettle and marginal shallows, together with an inlet, outlet, and an approach to the outlet. There are of course some conspicuous exceptions to this general plan as Enemy Swim Lake (South Dakota), with its peculiar sub-soil outlet, but such lakes present their special problems. The characteristic feature however of the impounded water basin is the dam, which for engineering reasons usually rises abruptly at the outlet end of the impoundment, taking advantage of the sheerest and narrowest part of the natural basin.

As a result back of most dams there is a large mass of water which is roughly the shape of a right-triangle wedge with its base resting against the dam and its hypotenuse extending along the floor of the basin toward the source of water. The deepest water therefore in these impoundments is usually near the dam and outlet, and the outlet—either spillway or penstock—is generally well above the bottom of this deep water without an approach of even moderately deep water.

The incoming water meets the interference of the dam and a zone of

slack water often of large extent is formed back of the dam in the region of deepest water. Here erosion silt, detritus and any sort of suspended matter which the inflowing waters may be carrying are deposited, at a rate back of many dams alarming even to the engineers. In this mass of deep, slack water the dissolved oxygen may be reduced to zero and ammonia compounds, sulphur derivatives and even carbon dioxide may accumulate in quantities dangerous to fish and other aquatic life during the summer months, if the intake water carries even a moderate load of organic detritus. In Lake Wilson at Florence, Alabama, for example, which receives the relatively unpolluted waters of the Tennessee River, during the months of July and August (1931) the dissolved oxygen below the fifteen meter level was almost negligible for some two miles upstream from the dam and during this period the dissolved carbon dioxide frequently rose above the limits usually tolerated by fish.

This zone of deep slack water back of impoundment dams presents and accentuates many of the usual hazards to fish life and bottom fauna attendant on stream pollution, organic detritus and other factors as may be readily recognized. One of the less expected hazards to fisheries presented by the deep water back of impoundment dams, which our field studies have brought out will be presented in this connection.

A few years ago when the Lake of the Ozarks (a power dam lake in central Missouri) was near the height of its initial production period, the dissolved oxygen in the deep slack water back of the dam was almost wanting and the dissolved carbon dioxide stood at a high level during the months of February and March, due to the oxygen demand in this case of organic matter, chiefly trees, brush and other plant material, left on the floor of the lake before filling.

This combination of low oxygen and high carbon dioxide in the deep water was maintained into late April when the lake was beginning to warm up. A sudden cold spell and a wet snow followed by rain brought a large mass of cold water into the lake as the run-off poured in through the Osage River and tributaries. As a result this mass of cold water moved down the lake along its floor into the deep basin back of the dam where the cold water stopped by the dam lifted the warmer oxygen-free, carbon-dioxide-rich water into the upper levels of the lake and forced this water back upstream some distance. Fish of all sorts were killed by the thousands and windrows of dead fish floated ashore. Shortly the water was mixed and reaerated so that no evidence of the cause of the catastrophe remained, and local explanations of the disaster included such ingenuous suggestions as that the lake contained "wood alcohol" from the decaying timber.

This type of catastrophe in impounded water has occurred several times to our knowledge in various artificial lakes and reservoirs where the dam and local weather conditions made possible this sudden stratification of water due to a temperature differential.

One remedy to offset the hazards of the slack water behind dams is

a bottom draw-off, penstock, or outlet for these impounded waters. The beneficial effects of bottom drainage are evident in natural waters like Crater Lake in which the dissolved oxygen is high and the carbonates and ionizable salts low all the way down through the 2,000 feet of water which this lake holds. We have traced the beneficial effects of roller dams opening at the bottom in such impounded waters as Lake Davenport on the Mississippi and the currents of well-oxygenated water can be followed through Lake Wilson at or near the level of the draw-off, but not in the deep water below the draw-off.

The other solution for the hazards of the dead slack water back of dams is not so simple, namely, to prevent the introduction of organic detritus and erosion silt. However, one body of impounded water which is practically free from erosion silt and organic detritus may be mentioned. Lake Tocoa in northern Georgia, a power dam lake, has the benefit of a low draw-off opening, and receives water carrying almost no erosion silt and organic debris. As a result the water of this lake is clear and well oxygenated to the bottom, and the floor of the basin is free from silt deposit, making Lake Tocoa one of the finest bodies of impounded water we have thus far examined.

Age of the Impoundment

As compared with natural lakes all of our impounded waters are still young and if left undisturbed by man would require years yet before the balance of forces is completely adjusted. There are many obvious changes going forward in impounded waters which have bearing on fisheries problems, such as stabilization of banks and the floors of the basins, the ecological successions of plant life and aquatic animals attendant on the rapidly changing conditions in the new impoundment which must be passed by here. One problem, particularly serious in connection with the practical handling of fisheries in impounded waters may be presented however, since more less indignant or at least impatient groups of sportsmen are demanding the answer at most of the new artificial lakes.

Almost without exception any newly created body of impounded water, if of course stream pollution and stagnation due to inadequate intake be avoided, will be productive, often amazingly productive during the first few months or years after the dam is closed. The actual length of this period of high productivity depends upon many factors, but an initial period of high productivity is outstanding in the history of practically all artificial lakes and impounded waters for which we have data.

In many instances the fish production has been so great that anyone could catch the limit in record time—and since seeing is believing for most people at least, during this initial period the lake-side real estate agent is in his glory, for strings of fish make an argument which will undermine the pocket book of almost any sportsman.

The field and analytical studies of recently impounded waters show

a simple explanation for this initial period of high productivity, as during this time the fixed nitrogen, phosphates and ionizable salt contents of the water are satisfactorily high. These favorable biochemical conditions are produced by the solution of material leached from the organic debris, chiefly trees, brush and grass left on the floor of the basin before flooding.

It is well known to zoologists that dry grass and rain water, i. e., a hay infusion will for a time produce quantities of bacteria and on these countless protozoans, chiefly ciliates, will feed. So, from the fixed nitrogen of the plant material leaching in the water a nitrogen food chain for higher aquatic animals can be started with bacteria and protozoa as basic links. However, after a time, when the fixed nitrogen of the plant material has been exhausted production will fail and more grass must be added if life in the culture is to continue.

So it is with the recently impounded artificial lake, and the production of fish food particularly around the margin of the lake is conspicuous even to the casual observer during the first period after closing the dam. Actual field studies at this time show high counts of plankton, lower algae, protozoa and rotifers, with increasing schools of minnows and small fish feeding thereon. But this initial period of high productivity is the cause of one of the most annoying problems which the local fisheries authorities have to face.

Fixed nitrogen is an absolute requirement for protein formation in living things, (excepting certain bacteria) and without protein there can be neither growth nor reproduction. Theoretically the nitrogen cycle is self-perpetuating once the balance is established, but actually in the case of these impounded waters nitrogen is lost as ammonia into the air and in the escaping waters leaving the lake, and is removed as protein in each fish caught, so that the nitrogen cycle is being constantly diminished in an impounded lake.

New fixed nitrogen must be added therefore if the food supply and finally the fish are to survive. The supply of leachable materials in the submerged detritus is gradually exhausted or rendered unavailable by blankets of silt and both the nitrogen and phosphate levels of the impounded waters fall, with a resultant decline in the supply of food for fish. As fishing begins to fail the local authorities are often blamed for inefficiency, although they are in no wise responsible for this natural decline in available basic material for fish food. The pond culturist knows that fresh fertilizer must be added to the pond from time to time if the food supply is to be maintained, yet no new sources of nitrogen and phosphates are available in the impounded waters to replace the organic debris covered by the water when the dam was first closed. So the impounded waters tend to come to balance at a lower level of productivity.

Restocking programs are not entirely successful in restoring impounded waters to the initial phase productivity even if these waters

have been over-fished, and the problem of raising and maintaining higher nitrogen and phosphate levels in impounded waters after the leaching of the original debris has been completed, is a difficult one.

The annual draw-down of some impounded waters is a partial solution, yet the draw-down may be the cause of serious disturbances to the fish fauna, which may more than offset the value of the draw-down in restoring nitrogen and phosphates.

If, however, the draw-down in such impounded waters as have a draw-down, lay bare sufficient areas early enough in the season to permit these areas to grow up in weeds and other vegetation, and if these uncut plants are subsequently flooded in the spring, some addition to the fixed nitrogen and phosphate supplies of the impounded waters may be made. It has been difficult however to work out such a program, as the draw-down in the same body of water varies from year to year to meet other needs which are generally considered by those in charge as more important than fisheries.

In fairness to all concerned the facts that newly flooded areas will have for a time a supply of fish food exceeding that of natural lakes, and that this food supply and the amazing catches of game fish attendant thereon will drop after a time to a lower level, during a sequence of natural happenings resulting from the rapid aging of impounded waters during the first few years of their existence, should be borne in mind in planning the fisheries program of such impounded waters.

Water Supply

Most natural lakes have definite inlets and outlets through which water moves continually and although there may be some fluctuation in the water level in these lakes it is usually of little importance to the biota since the outlet and inlet are more or less in balance. With impounded waters the water supply problem is quite different, as the supply may be constant or intermittent and may vary greatly in volume from time to time, all of which changes will be projected onto the impoundment by the dam which is built primarily to retain and conserve the water supply. Conditions resulting from the water supply may vary therefore in impounded waters from those in Lake Keokuk, where the entire flowage of Mississippi River is dammed and brought up to a relatively constant level for power plant purposes, with the excess water passing over a spillway, to Mud Lake Irrigation Reservoir in Idaho, where in late summer there is no intake of water at all. Yet both of these bodies of water are supporting fish faunae under of course widely different conditions.

On the basis of water supply three types of impounded waters can be recognized each with its own set of fisheries problems, namely the pond-type, the lake-type, and the river-type, with numerous intergradations.

Pond-type. In the pond-type the water supply is intermittent and often inadequate, during a portion of the year, to replace the water lost by evaporation, so that concentration of electrolytes in the water, the inroads of aquatic vegetation, and depletion of oxygen may all be hazards in this type of impoundment.

For this discussion, the American Legion Lake in the Black Hills of South Dakota will serve as an example in presenting one set of hazards to fishes in the pond-type of impoundment. During the past summer the extended drought reduced the flowage in the small stream feeding this lake, to a few inches. The stream water was cold however, well oxygenated, satisfactory in salts and nitrogen, and was supporting in the stream, trout and other fishes. The volume of this stream finally decreased so that for a few days the inflow was not sufficient to make up the loss by evaporation and no water went out over the spillway. As a result the lake warmed slightly but not enough to damage the fish in the lake. However this change in temperature together with the loss of flowage through the lake was sufficient to provide conditions favoring an overwhelming growth of desmids and small algae, so that the water of the lake became green with these suspended organisms. When their growth proceeded far enough the oxygen requirements of these plants reduced the dissolved oxygen in the lake at night to a level fatal to trout, and many fine fish died, in spite of the fact that the dissolved oxygen during the day rose to above seven ppm. and water conditions were otherwise satisfactory during both night and day.

The pond-type impounded waters which include many of the smaller artificial recreational lakes, and irrigation reservoirs should always be checked therefore for an adequate water supply before these impoundments are included in a program of fisheries development.

Lake type. Several of the larger impoundments in which the water intake is sufficient to overbalance the loss by evaporation and yet in which the inflow of the impounded stream is not the major factor in the hydrodynamics, approach true lake conditions except as these impounded waters are disturbed by draw-down. Elephant Butte Reservoir in New Mexico and the San Carlos Reservoir in Arizona are lake-type impoundments.

River-type. Many impounded units are so overwhelmed by the stream which is the source of the water, that they are little more than wide and sluggish portions of the river, and are subject therefore to all the hazards which the river may bring plus others due to the slowing down of the stream flow. Lake Keokuk in the Mississippi River is typical of this group. In this mass of impounded river water river conditions dominate from the surface to the bottom, but the slowing down of the current has caused heavy silting in over four miles above the dam, with destructive changes to the bottom fauna, since both the erosion silt and organic detritus loads carried by the Mississippi are heavy.

From Lake Keokuk on the one hand, many sorts of gradations have been found in the river-type of impounded waters to Lake Wilson (Alabama) on the other. During the summer months Lake Wilson consists of two very distinct units, namely, a river (the hyperlimnorrheum) some fifteen to fifty feet deep flowing over a lake (the hypolimnion) of almost dead water extending from about the forty foot level to the bottom (ninety to 100 feet). Between these two units there is a narrow transition zone having a definite thermocline, and oxycline, and carrying a band of silt, i. e., a band of silt is carried in the almost oxygen-free, but sparkling clear cold water of the submerged lake. Thus in Lake Wilson the problems of light penetration, distribution of dissolved gasses, and various other biochemical and biophysical factors which materially influence both bottom conditions and productivity, are distinctly different from either a true river or a natural lake.

Water Removal

Of all the factors producing fisheries problems in impounded waters, the disastrous effects of the draw-down are perhaps the most easily recognized. Nesting areas are exposed at the height of the spawning season, lateral areas and beds of submerged vegetation productive of fish food are suddenly left to dry, and both young and old fish are often forced into waters unsuitable or even lethal for fish, by the draw-downs which lower the water level abruptly and which mix dead slack water with surface waters. These draw-downs however must be made often without warning, to meet the needs of power plants, navigation or irrigation. And yet, hopeless as the situation may seem, especially to the fish, solutions for these problems are beginning to appear. Lateral areas tributary to the main impoundment but with maintained water levels not subject to the draw-down have provided shallows and submerged vegetation for young fish and spawning grounds as well; floating bass nests which ride at anchor and maintain constant water level conditions regardless of draw-downs, have been used with large success on certain power-dam lakes in Georgia; and still other less proven devices are in the offing, to meet the various hazards of the draw-down.

Conclusions

In conclusion, field and analytical studies show that most bodies of impounded water are not true lakes, as compared with natural lakes, and that these impounded waters have a variety of problems peculiar to impounded waters. There is no question concerning the enormous fisheries development possible in impounded waters, but in view of past experience and the existing findings closer cooperation in planning between those constructing the dams and making the impoundments and those intrusted with the fisheries interests is urged, in advance of the construction. Many things helpful to the fisheries program can be

included in the construction program without altering the efficiency of the final impoundment for the needs of industry, navigation or irrigation.

Discussion

Mr. Lee S. Roach (Ohio): We have not had any conference with Dr. Ellis, but the close correlation between the factors he has found and those which we have found as a result of our work would almost seem to indicate that he must have read our paper. We have not had the staff to follow up in detail some of the problems that he has mentioned, although in our artificial lakes we have noticed this dead oxygen condition over the bottom, and the slides you will see this afternoon, showing a lake which has a bottom outlet for that dead oxygen with its layer of water, will be of interest to most of you. Meander Lake in the eastern part of the state was stocked in 1932 with 1,250 fish, 500 crappies and 750 bullheads. In the spring of 1935 Mr. Langlois had a crew of fishermen there with trap nets—by the way, in the meantime that lake was closed to fishing; it was the principal domestic water supply lake—in the spring of 1935 over 135,000 fish were taken out, most of which, 116,000, were crappies. That was when the lake was about three years old; they had an increase in productivity the first few years of their existence.

Dr. Ellis' paper has taken a lot of our material for this afternoon, which is possibly a good thing, with all the papers that there are on the program; we can eliminate references to many of the things he brought up.

Dr. Hubbs: When I offered a slight word of criticism a few moments ago, which was intended in a constructive way, I should have elaborated a little bit and made some exceptions. The outstanding exception would have been the work of Dr. Ellis on pollution, on silting and on impounding problems. That work is an inspiration to all of us who have followed him, and we do hope it will be continued and extended.

I would like to add a word or two of suggestion with respect to some of the points which he so ably raised. There is another problem which no doubt he has fully appreciated but perhaps has not had the time to go into, with respect to lack of oxygen in the cold deep water just behind the dam, and that is in relation to the problem of releasing a certain amount of that bottom water in a steady current during the warmest months of the year in order to create trout water in the river below. I have no doubt Dr. Cahn, Wildlife Director of the Tennessee Valley Authority, will take up this point in connection with the plans to make trout waters out of the river below the north dam in the T. V. A. territory—a wonderful opportunity for that great mass of cold water if liberated at least a few weeks of the year in order to produce water sufficiently cold below. But if that water has an accumulation of nitrogenous matter and a lack of oxygen and high carbon dioxide, some arrangement must be made by the fish managers in that area for very thorough aeration of that water as it is liberated.

Another point is this: I hope he will not be pessimistic with regard to efforts to retain that high initial productivity in these impounded waters. We have observed that; it is more or less universal and must be accepted. There are many materials in these flooded lands—I recall examining one of our newly flooded ponds in Michigan; looking down on the bottom I could see what looked like smoke rising from a chimney. On closer examination I found it was a cloud of Daphnia, the finest sort of fish food, arising from a pile of cow dung in the bottom of that water. There should be some way of adding chemicals—perhaps hay infusions could be added, but some way ought to be found to maintain that high productivity, because it may be possible to maintain an even higher productivity in some of these impounded waters than in some of the natural waters if they are properly managed.

MR. LANGLOIS: One of the difficulties involved in maintaining that productivity by periodically adding extraneous material arises out of the fact that these lakes are usually intended for bathing as well as for fishing, and unless some definite method is adopted of deciding in advance that the lake in question shall produce either fishing or swimming, I do not think such a program of fertilization will be practicable.

MR. R. W. ESCHMEYER (Michigan): The question has been raised of the effect upon a lake of putting in brush in order to protect certain species of fish. I believe no one would be better qualified to comment on it than Dr. Ellis, and I wonder if he would give us his opinion in the matter.

DR. ELLIS: Fresh brush and trees do contain some nitrogenous material, and that contributes to the first or initial rise of nitrogen. If this material be left in excess in the bottom of a lake, there is only a small quantity of protein in it, the cellulose which remains behind continues to disintegrate over a long period of time and can cause an oxygen demand. That was the chief difficulty in the Lake of the Ozarks—the nitrogen had been very largely released but this material still in the lake was demanding the oxygen and producing carbon dioxide. There is evidence also that it liberates tannic acid and some other compounds of disintegration of cellulose, so that too much is more than you want. That is true of sawdust and other wood materials which at least yield only a small quantity of nitrogen and phosphates but still remain a potential hazard. In general, therefore, from the point of view of the fisheries I favor the removal of the bulk of brush and trees, to say nothing of the menace to navigation, swimming, and so on. It is advocated that this material be left as refuges for fish, but it seems absurd to talk about a tree which is seventy feet under water being very much of a refuge for small fish of the minnow type and others that run around shore, so that the argument does not hold. The value of the tree material after it is leached is relatively small.

MR. ELLIOTT S. BARKER (New Mexico): Have you any data as to the number of years that must elapse before your lake will reach the peak of productivity, and then how many years it takes to go down to what you might term the final level of productivity of fish and fish food?

DR. ELLIS: That varies with the lake, with the size of the basin and with the amount of material left in there—it varies with local conditions. In this particular case, the Lake of the Ozarks, the productivity ran up in the first eighteen months and then after that time dropped down. Lake Murray in South Carolina took about five years to reach its peak. Lake Murray is in acid soil; conditions of pH and other things going into the water are quite different from the Lake of the Ozarks, which comes out of a limestone country and has an entirely different salt balance. So you have to take the salt balance, the amount of material drained and the amount of material left behind, and add to that the factor of drainage of water by the power company. If the power company takes it off when the leachings are at their best, then you lose all that nitrogen. It has to be figured locally on the conditions applicable to the case in mind. Therefore each of these impounded waters should be studied before the fish program is approved. I would not say it takes six months or two years to reach its peak, but certainly the first four or five years will include the peak.

MR. ESCHMEYER: I think Dr. Ellis will agree that occasional brush shelter would not injure a lake, otherwise most of our Michigan lakes would be ruined, because they have a certain amount of brush in them.

DR. ELLIS: I am talking about brush left on the bottom; you mean brush in more or less shelter?

MR. ESCHMEYER: Putting back an occasional shelter, I mean.

DR. ELLIS: Certainly we approve of brush shelters along the shore, because many of these lakes have very little marginal water or shallow in which fish can take refuge.

MR. REID (Pennsylvania): I should like to ask Dr. Ellis whether there is

any serious objection to releasing water from the lower levels of an impoundment, assuming it is properly aerated, in order to get a lower temperature in the trout waters below a dam.

DR. ELLIS: In Lake Wilson when the surface water temperature was around 29 to 30 centigrade, below the 15 meter level the water temperature was 7 centigrade or less, so that you have a mass of cold water at the bottom of Lake Wilson. At this time if one could be on the bottom looking up through the water he would see a band of silt at the bottom of the warm water; for the warm water flowing over the surface of the cold water carries a silt load, and because of the difference in density of the cold water below and the warm water above, the silt during the summer months does not pass through the warm zone into the cold zone, consequently the bottom was not only cold but sparkling and clear. This water could be drawn off for trout rearing if desired, but it would be necessary to re-aerate it, since it carried little or no oxygen, to blow off the excess carbon dioxide which it usually carried, and to remove various other compounds, some of a highly toxic nature, which do occur in this deep cold water from time to time.

MR. ALDRICH (Oklahoma): Those who live in an area of impounded waters and artificial lakes will appreciate the remarks of Dr. Ellis. I would like to verify what he has said in regard to the peak, particularly in Oklahoma where all of our lakes are impounded. The average for the peak of production is from three to five years, depending of course on the depth, and so forth, of the lake. Most of the lakes in Oklahoma are used for the purpose that has been mentioned here, namely domestic consumption; practically all of the impounded reservoirs are used for water supply. Fortunately we have worked with the health departments and still have permission to fish on municipal water supply areas, but we have to proceed very cautiously. The health authorities insist on the removal of vegetation, and so forth, and desire a minimum of organic matter. That condition of course is not so productive of fish life, so that we have had to resort to artificial propagation to restock these lakes, and make no effort to build up the fertility of the water itself.

MR. HENRY C. MARKUS (New York): With regard to the reference made by Dr. Ellis to hay infusion, we know that when you have a hay infusion that has run its cycle you add a little more hay or organic matter to it and reproduce it again. In our artificial lakes the fish people are often unable to do that after the peak has been run, and we are left at a handicap as to what to do to bring it back. Two groups of people are responsible for that, and I think they should co-operate with us; I refer to the Department of Agriculture and the Department of Forestry. These agencies should put the land back into a productive condition so that it will furnish the organic matter to our streams and lakes—by the way, it applies to the natural lakes as well as the artificial—and bring back the organic matter that is necessary to keep up this life.

DR. HUBBS: We have had dozens of confirmations of Dr. Ellis' findings in Michigan in another line of study, namely, that of the relationship between beaver and trout. When the beaver produces an artificial pond we get an enormous increase in the productivity of trout in the first year. There will be an increase in the second year to a tremendous crop; ordinarily in the third year there is a slight decrease, in the fourth year a big decrease, and in the fifth and sixth years the productivity usually falls off entirely. Sometimes the peak comes later, sometimes earlier. Sometimes the falling off is more rapid, sometimes not, depending on local conditions, temperature, etc. But we do have a tremendous number of confirmations of his findings, therefore his conclusion must be a general law.

In reference to the question asked by Mr. Eschmeyer, I think what he had in mind was not the leaving of an enormous amount of brush in the bottom of his lake for shelter, but a rearrangement of a certain amount of material in the form of shelters in shallow water. We certainly realize we can get too much, and

from the standpoint of shelter for young fish we can also get too little. I hope Dr. Ellis will give attention to the question of determining how much material we can leave in the lake for shelter without giving rise to any disadvantages from the chemical point of view.

Another possibility has occurred to us in respect of natural lakes more or less akin to this, and that is the question whether there is not available an enormous amount of bottom material containing compounds which are needed in the shallows and which by some method could be released for that purpose. If so it would be a simple matter to put in a suction dredge and pump a volume one-eighth of an inch thick of this bottom material over some of the shallows of the lake, thus releasing in the shallow circulating waters the products of the leaches of some of this bottom material. If there is any possibility in this, there is an absolutely unlimited amount of material which could be provided as a fertilizing agency.

Dr. Ellis: That is a splendid suggestion. We have made a chemical analysis of the bottom muds in a variety of lakes and ponds. In some Mississippi impoundments we have found kheldahl nitrogen to be six per cent. If that material could be pumped out and made available, with the sulphur compounds and other toxic substances which this mud frequently contains taken out—they might prove harmful unless they were removed—it certainly might be of advantage. But the nitrogen is there, particularly in the impoundments of the Mississippi, where municipal sewage and other sludges carrying nitrogen have been allowed to pile up.

Dr. Thompson (Illinois): Down near Cairo, Illinois, we have followed the method which Dr. Ellis suggests. In this case the lake lay dry for about a year and there wasn't much growth over its bed. I do not think the condition was due to the grass or vegetation but rather to the fact that the bed lay dry. When it was refilled in 1931 or 1932 we immediately had a huge increase in game fish production, reaching the peak in 1934, when we made a detailed survey, with unusual catches of game fish, and the decline shown by another survey this spring apparently reached the peak after about two years. It behaved just like a new lake. This lake was formerly a cypress swamp and had the usual characteristics of such areas.

Dr. John R. Greeley (New York): In a survey of the lower Hudson area this summer we had an opportunity to study the New York city water supply system, which includes a lot of lakes which have apparently got to a rather stable condition. Some of them do produce very good fishing, even though they have gone through their time of maximum production and have got down to a more or less stable condition. A number of the outlets are built from the bottom; the water is cold, and the point Mr. Reid mentioned about the trout stream possibilities is an interesting one in connection with these sources of New York water supply, from the point of view of the cold outlet water maintaining conditions suitable to trout in the intervening sections of stream. An outstanding example of pike production is the Sacandaga reservoir. The pike fishing is splendid there, but we have noted a tendency for it to taper off now, and it is an unstable condition, as Dr. Ellis mentioned.

Professor W. J. K. Harkness (Ontario): There is a situation in Ontario that might be of interest in this connection. About a hundred years ago there was a canal system running across the southern part of Ontario known as the Trent Valley canal system. About two hundred lakes are used as a reservoir system for this canal, all controlled by dams. In the construction of some of these dams, vast expanses of low lying land were flooded to a depth of six or ten feet, and fairly large artificial lakes were formed in that way. This water was originally muskellunge water. The muskellunge seemed to take naturally to the flooded area in which the trees were cut; the stumps are still left to the surface of the water and coming above. The area has grown up, of course, fairly thickly, but not too densely, with vegetation. These flooded areas in my estimation—and I would like to ask Dr. MacKay's opinion of this—have been a factor in main-

taining the maskinonge in these waters; and I may say that the condition to which I refer has prevailed for I suppose sixty or seventy years. Do you not think, Dr. MacKay, that they are a very substantial factor in maintaining our maskinonge in Ontario?

DR. MACKAY: Yes, I do.

DR. RODOLPHO VON IHERING (Brazil): Mr. Chairman, we have not had time to prepare a formal paper; perhaps we may have one in time for publication in the Transactions. But I wish to make one or two brief references to the matter dealt with by Dr. Ellis, the question of impounded waters. It is a question of some concern to us in Brazil, because we have there a large number of assudes, as we call them. They run from one million cubic meters to several hundred million; some of them are over eight hundred million cubic meters. We started our studies with the smaller ones; Dr. Stillman Wright, my colleague on the Commission, worked out limnological studies, and, as may be seen from the publications of our Commission, his results are more or less the same as yours. Of course the climatic conditions of our country are different from yours in that we have no winter, and during the whole of the year we have only slight variations in temperatures; consequently the plankton are quite abundant all the year around. So it will be obvious to you that as we listen to the results of your studies we find them very useful to us as general ideas but we cannot put them into effect in our country in just the same way; we have either to adapt them to our own conditions or employ methods which are different but suited to our own needs. We have to try to provide good fishes for the people of our country. Assudes are being built to a greater and greater extent, and naturally when they are built they contain no fish with the exception of some small species from surrounding ponds, and it is necessary that we obtain bigger and better ones from elsewhere. So we go to the Amazon and the San Francisco rivers and take from them species which are adapted to the conditions in the assudes, and in addition we carry on hatchery operations to stock these waters. But there we come up against difficulties which I am sure you have never had to face. Let me give you one instance. We have in Brazil the catfish *(Pimelodus clarias)* which grows to a size of two and one-half kilos at maturity. In the San Francisco river it takes this fish three or four years to come to maturity, so we take fingerlings ten centimeters long and sixty grams in weight and put them in the assudes. Six or seven months afterwards these fish develop to a weight of six hundred grams, an increase in weight of ten times what it was when the fish were put in; and in size they grow from ten centimeters to twenty-seven or perhaps thirty in six months; in one year they reach one kilo in weight. But the peculiar thing is that they become so fat they do not develop their gonads—I do not know why; it may be a general rule in biology that when the fat is accumulated to too great an extent, the gonads will not develop. So we could not have spawning from these fishes brought from the San Francisco and put in the assudes, they become so fat and even humpbacked. It therefore becomes necessary to handle them in such a way that they will not grow so fat, then they will produce eggs and fish may be produced from them.

Our fish do not spawn like yours, from year to year; they spawn only on certain occasions, particularly after a heavy rain when new water is brought into the ponds. If you do not get this exact moment you cannot have eggs, especially for stripping and fertilizing, so we have had to devise a method of dealing with that, which consists of injecting into the fish an hypostasis; and after this operation—sometimes performed once, sometimes repeated several times—the eggs become ripe and capable of being stripped and fertilized from five to eight hours afterwards.

Many of these problems you do not have to face, and in that respect we have to go our own way; nevertheless the studies you undertake here and the results you obtain from the general point of view are of great help to us. So that if you can once in a while help us, especially when we apply for information as to your experiments and results which could be useful to the Fishery Commission of Brazil, we shall thank you heartily for it.

SOME STUDIES OF IMPOUNDED WATERS IN OHIO

E. L. Wickliff
and
Lee S. Roach

Bureau of Fish Management and Propagation, Ohio Division of Conservation, Columbus, Ohio.

Limnology is a very young science, yet in its less than fifty years existence as a distinct science it has made great strides. In the past few years its values have been demonstrated many times and the application of limnology to practical fisheries problems and management practices has proven its worth.

In all the practical problems dealing with fish, the problem of habitat is without doubt the most important. Regardless of the millions of fish produced and reared in fish hatcheries over the country, unless they are released where conditions are favorable they will not thrive or continue to reproduce themselves. In Ohio approximately $100,000 is spent yearly in purchasing and propagating fish. To date little has been done to find out what happens to the fish after they are stocked in our waters. What few returns we have had on tagged stocked fish have shown a decided downstream movement. In fact, tags from Ohio's fish have been returned from four states.

Many practical problems arise which should have careful study. All the factors of the environment of fishes should be studied as a unit, not as isolated problems. The physical, chemical and biological interrelations should be considered as a chain, not as a group of links. Such physical factors as temperature, turbidity, silt, water levels, etc., should be linked with the chemical factors, principally oxygen, carbon dioxide and acidity, and these all tied in with the aquatic life, such as the vegetation, the phytoplankton and zooplankton and the bottom organisms. After all the trite phrase, "a chain is as strong as its weakest link," still holds true.

Variations in these links often occur. Some occur naturally, some are caused by man. It is the extremes in these factors that should have study. When do the extremes come? That is why it is necessary to carry out a regular study at all seasons over a period of years. The scientific method is "to gather all the facts before beginning to work."

Naturally the first requirement for fish is water. It should be clean water—not necessarily pure enough to drink. Low dams provide water. During such summers as 1930 and 1936 they were very beneficial. They are naturally a form of stream improvement. But just because there is an increase in the volume of water, does that mean there is room for more fish. True, there is more space, but how about food? What about

the other factors,—are they increased in proportion to the water? Would it not be wiser to carry our aquatic improvements beyond the mere mechanics of furnishing more space for fish and to try to improve food or other conditions to gain greater productivity from a given volume of water?

In Ohio we have classified our impounded waters into two general groups: (1) Those in which the water has been impounded over a more or less wide area of bottom land not usually covered by the stream water. These we call our "Ponds," "Lakes" or "Reservoirs"; (2) Those in which the impounded area is merely a deepened and lengthened natural pool in the stream bed itself. These we term our "Low Dams."

We have a card file listing each natural and artificial lake in the State. The location of each has been mapped. Our cards contain such information as location in county and township, nearest road, year built (if artificial), area, length, width, depth, type of bottom, type of vegetation, river system, streams inflowing and outflowing, character of water supply, water level fluctuations, type of fish present, type caught and what other uses the lake may have besides fishing. For most of them we also have a small outline sketch. Most of this data was collected by our Conservation Officers in each county. We are entitled to make an investigation of those which are open to public fishing in order to get some idea of the physical, chemical and biological factors. This we are doing as rapidly as time will permit. Naturally, with our limited staff, most of the investigations are preliminary in nature. On the back of the cards mentioned we have all information as to the numbers and kinds of fish stocked.

Data compiled in this way shows that Ohio has 979 lakes and ponds, over 89% of which are artificial and may be classed as impounded waters. Of the 880 artificial lakes we have made investigations of fifty-seven in fifty of Ohio's eighty-eight counties. From these over 700 analyses have been made for dissolved oxygen and 400 for pH and free carbon dioxide. Over 500 samples of phytoplankton, 500 samples of zooplankton, and 300 samples of bottom organisms have been taken, identified, and counted.

Although our data on low dams is not as complete as that on the reservoirs, we have a map prepared showing the locations of all old dams in the State, (mostly mill dams), those that have gone out of existence and those that still remain, besides all new dams recently built. This shows that there are 358 old dams gone out of existence which would furnish good locations for new dam sites, and 383 dams now present in Ohio.

In addition to this information we have on file other data concerning each dam, such as when it was built, when it went out, what materials it was made of, its height and width and the type of stream in which it is or was located.

We have made preliminary investigations of only nineteen low dams

in eight streams, however, we are now following through a seasonal study of a small stream in which several dams are being built. Four have been completed to date.

Our work on Ohio's impounded waters was begun in 1932 by Mr. M. B. Trautman and the authors. Collections, counts, identifications and analyses were made on eight state-owned lakes and five municipal reservoirs. This work has been continued and expanded up to the present time. During the winter of 1935 some observations were made on three state-owned lakes. Since 1932 all the work has been carried on by the authors.

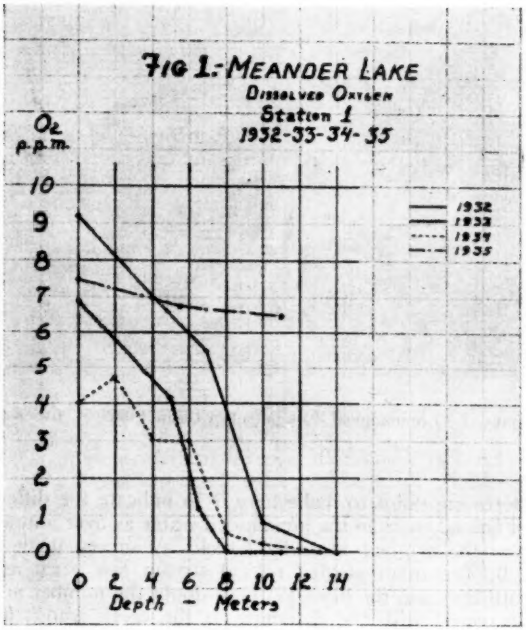
Our artificial lakes (larger impounded waters) ranged in age, when examined, from one month to ninety-nine years; in area from one to 16,420 acres; in depth from one to nineteen meters; in average summer temperature from fifteen to thirty degrees centigrade; in average turbidity from zero to four meters (Secchi); in pH from 6.2 to 9.1; in average dissolved oxygen from 0.3 to 9.7 parts per million; in average free carbon dioxide from zero to 13.3 parts per million.

Each reservoir differs from the others in specific instances and does not differ from our natural lakes more radically than from each other. Artificial lakes furnish a wonderful opportunity for management practices since they may, in a large measure, be controlled and rearranged by man to suit his desires.

Most of our artificial lakes are eutrophic after newly flooded bottom lands have become mature. The length of time elapsing between flooding new land and the complete maturing of its bottom depends on several factors, most important of which are probably the quantity of dissolved oxygen in the bottom water and the nature of the decaying organic materials on the bottom. The quantity of dissolved oxygen in the bottom water is also due to the depth of the water, the amount of wave action and the amount and type of decaying material. In all lakes examined, a depth of less than ten feet contained oxygen and the nature of the bottom at those depths indicated early maturity.

Some of the more important problems in the care of artificial lakes are: (1) fluctuation of water level, which not only affects spawning grounds of the fish but also the growth of rooted vegetation; (2) production and care of aquatic vegetation, and (3) silt.

The limnological history of Meander Lake, Mahoning County, has been followed yearly from the time it was seven months old. This is an artificial lake of about 1,200 acres. After two and one-half years' water was drawn off from the bottom, a decrease in dead coarser vegetation and an increase in midge larvae from nineteen in 1933, to an average of about fifty in 1934, was noted. In 1934 dissolved oxygen was present in all samples through thirty-three feet, except the bottom sample at forty-three feet. Meander Lake has a volume of one hundred billion gallons of water. The advisability of removing water from the bottom of smaller artificial lakes through the construction of gates at various depths, rather than overflows, can readily be seen. (Fig. 1).



Since this lake supplies domestic water for two cities in its vicinity it is not open to public fishing and has been used by the state of Ohio as a natural hatchery. When this lake was built practically all brush and vegetation was cut and removed. When the lake began to fill, only the vegetation that had grown in between cutting and filling was present. Although it was stocked with very few fish on April 29, 1932, 750 bullheads and 500 crappies, in the spring of 1935, 131,569 fish were removed for stocking other waters in the vicinity. These fish were as follows:

Crappies	116,651
Suckers	11,022
Bluegills	2,410
Bullheads	1,380
Largemouth Bass	43
Smallmouth Bass	3
Catfish	50
Bass (not classified)	10

These were almost entirely breeder fish.

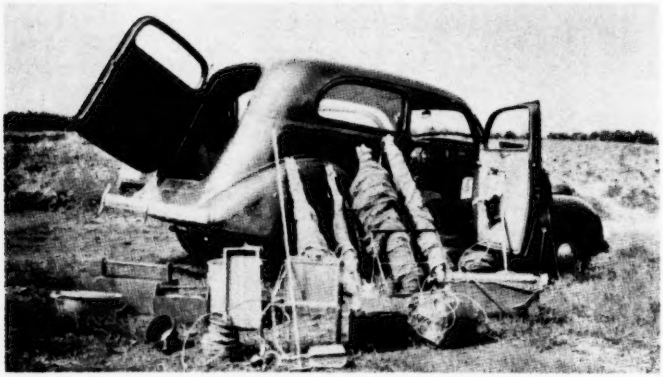


Figure 2. Limnological Equipment used in Ohio by the Authors.

An interesting point to make here is to indicate the difference in the species of fish taken from the impounded water as over and against those taken from the original Meander Creek. A survey made in 1929 by Mr. M. B. Trautman yielded typical stream fish, such as rock bass, smallmouth bass and the like. Without doubt the number and poundage of fish increased with the damming of the creek water, although the number of species of fish probably decreased. This lake was not built for fishing purposes and no structures, covers, or other so-called improvements were installed.

Lakes arranged according to their age show a production of plankton within one month after filling. Water up to one year in age averaged between two and three hundred water fleas per liter of water per lake. Indications are that after the initial year of a lake there is a decided drop in the amount of phytoplankton and zooplankton. It seems that previous to the drop, forage fish, such as the gizzard shad, might be introduced since they feed, as adults, primarily on algae. Later the bluntnose minnow, a generalized feeder, could be added.

Organisms such as mosquitoe larvae have appeared in new lakes within the first month. Within six months an average of eighty-three bottom-dwelling midge larvae were counted. At one year these had increased to an average of eighty-six. Variations from fifty-eight to 142 midge larvae per square meter (26-50 year old lakes) were found. (Table 1) Bottom organisms are apparently more dependent upon the nature of the soil in the bottom than on the age of the bottom and little information has been obtained on soil conditions.

TABLE 1. AVERAGE DATA ON OHIO LAKES*

	Total Bottom Org.	Bottom Org. Chiron.	Zooplankton	Phytoplankton
1 Month	743	0	?	?
6 Months	150	83	231	605,000
1 Year	470	86	295	284,000
1½ Years	116	60	70	56,000
2 Years	313	70	?	?
3-5 Years	257	60	65	268,000
6-10 Years	210	58	111	323,000
11-25 Years	211	78	108	650,000
26-50 Years	388	142	116	155,000
51-75 Years	199	130	44	182,000
76-100 Years	198	91	102	260,000
Average	300	86	125	309,000

*Bottom organisms as number per square meter. Zooplankton as number per liter.

We have felt at times that lakes, especially smaller ones, or the bays of the large ones, should be fertilized or limed before being flooded, in order to facilitate bottom decay and aid in a more rapid maturity.

As an example of the problem of silt—O'Shaughnessy Lake at eight years yielded an average of 161 bottom organisms, none of which were Chironomid larvae. During its tenth year this lake was drained and engineers, from measurements, estimated it had silted in six per cent of its original volume.

Suitable coarse aquatic vegetation is a great boon on any lake. Care in its planting and development should be practiced, however. Many instances have been brought to the attention of the Ohio Division of Conservation where individuals or organizations have spent much money on aquatic vegetation not adapted to the type of water in which it was planted or on plants which could have been obtained in other bodies of water in the State without cost. Since 1933 we have recommended a resident biologist at each of our state-owned lakes.

The absence of aquatic vegetation is not the only problem connected with management. Vegetation may become so abundant that although it manufactures oxygen in abundance on bright sunny days, night followed by dark days may cause a drain on the oxygen until absolutely none is left, in which case the fishes die. Under such conditions it is necessary to remove the excess vegetation. This we reported on at the 1934 meeting of the American Fisheries Society. An interesting point in connection with abundant vegetation is the fact that during early spring, many of the sanctuaries set aside by the Ohio Division of Conservation are apparently ideal for spawning and rearing, yet as the

summer progresses and vegetation becomes thicker, conditions in many cases do not remain so ideal for the young fish.

Lake St. Marys is a shallow lake of wide expanse. It is subject to violent wind action. A more or less broad fringe of cattails along its south shore and broken bands along the north shore are the only zones in which vegetation occurs. The cattails are very dense and the water in these areas is, to a great extent, lost to fish and waterfowl. We have recommended the removal of cattails and the construction of channels to the lake and the planting of non-emergent vegetation in those cleaned areas. This project is being worked on at the present time.

Milton Reservoir has another problem in vegetation. The lake has silted in to a large extent, making the bottom unproductive and only one species of submerged vegetation was found in the lake proper after an intensive survey. One way to control this condition is a well rounded program of soil conservation in the drainage area. Water levels also varied considerably. Last summer (1935) we advised planting coontail moss, Elodea, and a pond weed in a protected bay—holding this in by a wire fence until it could establish itself. The interested parties of the region guaranteed a stable water level (within limits) and a good growth of vegetation was reported until the drought lowered the water ten feet during the summer of 1936.

Few studies have been made on the suitability of winter conditions for fish life. From recent work (1935-1936) indications are that even after a heavy winter, like the one just past, open waters covered with ice are not devoid of oxygen nor toxic in any other way we could determine. Although we had to cut almost two feet of ice in some cases the water was in good condition in all open lake situations. On the other hand, bays and protected swampy, shallow areas—the same which were productive of excessive vegetation in the summer—showed oxygen depletion. Although ice cutting and pumping has been employed by some states to try to overcome oxygen depletion, indications seemed to show this was of little avail. It does seem to us, however, that if channels of sufficient depth were provided so that fish could move from this zone to the open lake in times of need, or if a few openings were kept in the ice for fish to come to the surface occasionally, a step would be made toward improvement of winter conditions.

We began work on low dams in Ohio in 1933. In all cases we have attempted to compare the values of the waters impounded with the natural pools and riffles of the same stream. In almost every case studied up to this time the created pools have proven poorer in almost every respect when compared to the natural pools and riffles in the same stream. (Table 2). Dissolved oxygen, bottom organisms and plankton have been less. Low dams, however, have produced a greater quantity and a more stable water.

Fluctuating volume of flow is perhaps the greatest shortcoming of the smallmouth bass streams in Ohio. The drought of this summer made

TABLE 2. COMPARATIVE DATA ON IMPOUNDED WATER AND NATURAL STREAM LOW DAMS*

STREAM	Created Pool			Natural Pool			Riffle	
	O_2	Bottom Organisms	Zoopl.	O_2	Bottom Organisms	Zoopl.	O_2	Bottom Organisms
Maumee River	4.8	400	76	9.3	1750	152	...	700
Miami-Erie Canal	6.1	100	?	...	...	?	...	...
Beaver Creek	5.3	1000	3	5.5	200	2	7.1	450
Caesars Creek	4.8	0	..	3.4	363	..	...	...
Wolf Creek	4.7	709	6	6.2	...	9	...	260
Macocheek Creek	4.2	75	2	6.0	490	4	...	...
Cuyahoga River	3.8	175	3	5.0	585	3	...	...
Average	4.8	306	18	5.9	677	34	7.1	470

*Oxygen in parts per million. Bottom organisms as number per square meter. Zooplankton as number per liter.

disconnected pools of the streams under our observation for about thirty per cent of their drainage area. The value of low dams has been to provide a more stable water, not only in preventing fluctuations but also in such other factors as temperature, currents, some chemical factors, the biota and in raising the subsurface water supply.

From our investigations of dams we have made tentative suggestions for the present program of stream improvement in the State. These are:

(1) Riffles should be retained. They aerate the water before it enters the impounded pool, serve as the home for many of our forage fishes and crayfishes, and are most productive of insects. The riffles of the Ohio streams we have studied averaged about 150 pounds of insect larvae per acre during the early summer. Flooding riffles destroys nearly all the insect larvae normally living there, with the possible exception of one or more species of mayflies which will stay providing other factors remain favorable.

(2) Low dams should not increase the depths in natural pools in small tributary streams to much over forty inches. We have found in our general work that insect larvae and other potential fish food of the streams decreases to a minimum in pools of great depth.

(3) If possible, water circulation should be kept through the impounded area. This, we think might be accomplished by a "V" notch or weir. (Fig. 3). Three objectives are expected to be accomplished by this weir. The impounded pool will more nearly simulate a natural pool, which generally narrows as it approaches a riffle, and thus keep up a good circulation; a device is available to determine readily the stream velocity and second feet flow; the force of the water concentrated by the notch will tend to create a deeper channel connection to the pool below and allow for the passage of fish, doing away with the flat ribbon of water usually covering the stream bottom below a dam.

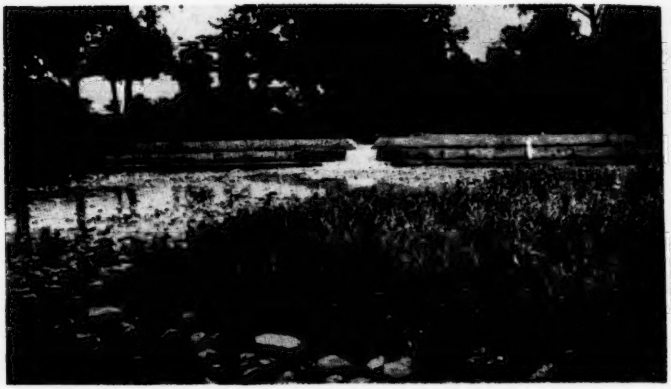


Figure 3. Notch in Dam to increase water circulation, which also provides easy means to determine stream flow, etc.

(4) If the stream bottom above the dam is sand or pebbles or small gravel, large flat stones at an angle with the stream bottom should have a tendency to add shelter for a larger variety of bottom life which will serve as fish food.

(5) If possible, dams should be placed below abandoned oxbows in the stream. Dead-end oxbows usually are rich in accumulated organic matter and are very productive of plankton and should serve as excellent natural rearing ponds for fish and fish food.

At the present time we are making a monthly study of two streams in Franklin County, Ohio. These creeks are being provided with different devices and we are considering the streams as our experimental projects. One point we have in mind is a type of "Subsurface dam" to be placed on riffles. It consists of a waterproof core placed in the stream bed on the impervious substratum with only a few inches above the riffle bed itself. We hope in this way to create water over the riffles by stopping the underground flow. These are still in the experimental stage and we hope to report on them at a future meeting.

In cooperation with Mr. Bryce C. Browning, Secretary-Treasurer of the Muskingum Watershed Conservancy District, we have started a preliminary study of streams to be impounded by the eleven large flood control reservoirs being built by the Federal Government and the Muskingum Watershed Conservancy District. The cost of these dams

amounts to close to $40,000,000 and the total area impounded by normal conservation pools will be around 16,000 acres.

We have suggested that trees or stumps be left in areas to be covered by water less than fifteen to twenty feet deep and possibilities of plowing or otherwise exposing shores underlaid with sand and gravel, to hasten the formation of this type of habitat for fishes which prefer it for spawning.

One other project we have underway is purely cooperative. The Division has obtained limnological equipment for two universities—Ohio University at Athens and Akron University at Akron. All the data obtained by workers from these institutions is to be made available to us in working up stocking and improvement programs. By furnishing apparatus and equipment to various colleges over the State we feel that we will gradually accumulate a mass of information about our waters and at the same time have available trained men for practical fisheries problems.

Discussion

Dr. W. Rushton (London, England): The impounded reservoirs in England are constructed for purposes of water supply only and therefore are not regarded with favor so far as fisheries are concerned. I am familiar with three impounded reservoirs in England that have been made for purposes of water supply but in connection with which some interesting questions with regard to the fisheries arise. Each is quite different in its character from the other, and the differences in what comes out of them follow in consequence.

I would mention first the Blagdon reservoir, which is the water supply for Bristol. The water supply for this impoundment, which was made more than fifteen or twenty years ago, comes off the limestone. At the present time it is still stocked with rainbow trout. They also rear the trout from eggs; it is the one impounded reservoir which is well known for its good rainbow trout. The eggs are hatched and the young fish put in as fry as soon as they have lost the yolk sac.

The second impoundment I have in mind is the one which forms the water supply for the city of Liverpool. It is known by the name of Lake Vrwny, and is situated in the Welsh hills. The geological formation there is pre-Cambrian. The reservoir was opened a few years after the death of Queen Victoria. It was made by damming the valley across; the depth of the water is eighty feet at one end, and it gradually shelves up to the shallows at the other end. It is about five miles long; it is supplied by two feeders which come from the uplands, and the water is slightly acid. This reservoir has been stocked many times with trout, which run to an average of twelve to fourteen inches long. The trout here are invariably thin, with big heads, the trout food being poor. Some time ago I examined some five hundred stomachs of trout from that reservoir and found the food to be invariably Daphnia, and the larvae of midges. The shallows are used for dry fly fishing. There is very little vegetation in the shallows because the water comes from a peat area, which is very acid, the pH averaging somewhere about 6. Trolling is done in the deep waters. These fish never develop into what might be called normal fish.

The third area to which I wish to refer is one with which I am exceedingly familiar, the Queen Mary reservoir, used for supplying parts of London. It was started just before the war and completed after the war. It is about five miles around, and the deepest part of it is about thirty feet. It was made by raising embankments, and the sides are composed of concrete blocks. The water comes

from the Thames, and the fish that are in there have been drawn in with the pumping of the water. The reservoir contains 5,750,000 gallons of water, and the fish found in it are largely perch, pike, and roach. It is against the policy of the authorities to allow anything to be done in the way of fertilizing these waters for fishery purposes, since the reservoir is used for the supplying of drinking water to the city of London. I am interested in the plankton of drinking water as well as of streams and rivers, and some six years ago my attention was drawn to this reservoir because of the condition of the plankton there. The water was perfectly red with the blue green alga *Oscillatoria rubescens*. The practice in connection with that reservoir was to fill it in the spring and use it intermittently when there was need for it, a practice which of course would not have the effect of keeping the water fresh. After this had been going on for some seven years it became impossible to use the water because of the condition brought about by the decomposing algae. The practice was then adopted of drawing out only the top water, so that the bottom water practically is never used. The difficulties arising in that regard were overcome by carefully drawing out the bottom water step by step over a period of a few weeks and thus getting rid of what you might call the stale water. But at least in our country, except in the odd case, it does not seem that you can have impounded waters and at the same time get good fishing.

PROFESSOR HARKNESS: I would like to ask Mr. Roach how he estimated his bottom fauna, how many samples he would take and for what acreage, the size of dredge, and whether he took samples across the whole lake or sampled intensely in one area.

MR. ROACH: We used the regulation Eckman dredge, 8 by 8. All our work has been preliminary in nature, and the number of samples varied considerably. In some cases, particularly in Meander Lake, we went across the length of the lake in series. In Pine Lake, which is more or less an oval lake, we took radiating samples. An interesting thing in Pine Lake was the fact that the closer you got to the shallow waters the smaller the midge larvae were, indicating that the larger ones had already emerged. As the summer progresses the fish go to the center of the lake. The lake is not deep enough to furnish a thermocline or anything of that nature; chemically the food conditions other than the bottom organisms are practically the same, so it must be that the fishermen follow the fish which follow the bottom organisms.

A COMPARISON OF SUMMER AND WINTER FISHING[1] IN MICHIGAN LAKES

A. S. Hazzard and R. W. Eschmeyer

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Michigan

Fishing in winter either by spear, tip-up or hand line has frequently been held responsible for poor fishing during the summer season. In recent years certain states have enacted laws to prevent or curtail the take of fish through the ice. In the fall of 1935 in Michigan the number of ice lines permitted was reduced by Commission action from five to two. At the time this reduction was being considered the Institute was asked to advise concerning the wisdom of the proposed action. The facts which we had, indicated that winter fishing was not generally a large factor in reducing the fish supply in lakes, but the evidence was then insufficient.

Owners of summer cottages, resort operators and others dependent in whole or in part upon the tourist fishermen who vacation in Michigan, fear that winter fishing may deplete their lakes so as to reduce the next summer's harvest. Particularly is this true if these objectors are not year round residents. They occasionally drive past their favorite lake in winter or see pitcures of it in the newspapers and are alarmed at the number of ice shanties or fishermen then in evidence. They do not stop to think that many of these shanties are only occupied on week ends or that the reason such pictures are published is often because they show an unusual concentration of fishermen. Nor do they remember that many of the species taken in summer ("largemouth" bass, "smallmouth" bass, rock bass, sunfish and bullheads) are protected or rarely caught in winter. The large winter catches which they hear about are also those which stand out in the memory of the narrator as unusual. It is true that at present there is no closed season on great northern pike and walleyes in certain Michigan lakes which have been designated as "pike lakes" nor in non-trout streams. Fishing for bluegills, perch and other pan fish is legal except from May 1 to June 25.

The proponents of winter fishing claim that ice fishing furnishes recreation in the out of doors at a time when it is especially needed and that they should be given consideration along with the objectors.

Opinions on the desirability of controlling winter fishing are numer-

[1] "Summer" fishing here includes the period from June twenty-five to September thirtieth; "winter" fishing, the period of ice fishing (usually from late December to early April).

ous and varied; the facts, as revealed by Michigan's creel census are interesting and suggestive.[2]

Both the general state census which has been carried on for the past eight years and the intensive census of total fish yield on certain lakes contribute to the solution of the problem. The former is a random sampling of the fishing, carried on by the Conservation Officers in their regular pursuit of enforcement duties. Fishermen are contacted and are asked to report their catch for the day up to the time they are approached. The officer records the number and average length of each kind of fish taken, the number of undersized fish returned, the manner of fishing, hours spent on the lake or stream, etc. These reports are sent in to the Institute where the data are transferred to cards for machine or hand sorting and tabulating. Such a sampling yields valuable qualitative data but does not indicate the total number of fish taken from any one stream or lake during given periods. During the past three years complete or nearly complete records of the fishing for various seasons in certain lakes near C.C.C. camps have been secured through the cooperation of the Michigan Emergency Conservation Work and the States Division of the National Park Service. This year complete fish catch records on many additional lakes are being taken by the above agencies and in the Waterloo and Yankee Springs Projects of the Resettlement Administration. Methods employed in taking and analyzing these data were described by the junior author (Eschmeyer, 1935).

The data for this paper were taken from the general census for 1935 and from other Institute reports of general census on Michigan lakes. Intensive census on six lakes in both winter and summer now contribute the most valuable comparison yet available of the effects of the two types of angling on given fish populations. In order to throw further light on the nature of winter fishing, intensive census data for eighteen additional lakes are included.

Comparison of Winter and Summer Fishing

Methods of fishing: The methods of fishing in summer are varied and well known. Winter fishing in Michigan is carried on in three ways: spearing (for great northern pike, muskallonge, suckers and other coarse fish) in January and February; line fishing with a short, limber rod; and the use of tip-ups. Spearing in shanties with decoy minnows is a popular sport on lakes containing pike.

A comparison of spearing and line fishing (Table 1) on six lakes where both methods are used shows that approximately one-third as many fish are taken per hour by spearing but that the average size of such fish is more than twice as great as those taken by line. Great

[2] Since the preparation of this manuscript a discussion of the possible effects of ice fishing has been published by T. T. Odell and W. C. Sehning, pp. 120-121 in A Biological Survey of the Delaware and Susquehanna Watersheds. Suppl. 25th Ann. Rept. N.Y.S. Conservation Department, 1935.

TABLE 1. COMPARISON OF LINE FISHING AND SPEARING, INTENSIVE WINTER CENSUS ON SIX MICHIGAN LAKES (PERIODS OF CENSUS ARE GIVEN IN TABLES 2 AND 3)

Lake	County	No. of fisherman		Hours fished		Catch per hour		Ave. size of fish caught		Ave. size of northern pike caught		Catch per hour of northern pike	
		Line	Spear	Line	Spear	Line	Spear	Line	Spear	Line	Spear	Line	Spear
Houghton	Roscommon	3,169	1,024	17,973	5,965	0.22	0.11	12.0	21.2	21.3	21.7	0.05	0.11
Fife	Kalkaska and Grand Traverse	142	332	715	1,383	0.21	0.09	11.8	22.8	25.2	25.4	0.02	0.07
Crescent	Oakland	266	69	767	247	0.19	0.06	9.1	23.9	17.0	24.1	trace	0.03
Round	Jackson, Washtenaw and Lenawee	4	43	8	169	0.27	0.04	8.0	28.6	....	28.6	....	0.04
Wamplers	Jackson and Lenawee	98	650	520	3,591	0.18	0.08	11.1	21.8	20.2	21.9	0.03	0.08
Hess	Newaygo	947	18	4,890	96	0.43	0.13	8.9	19.5	21.5	19.4	0.08	0.11
	Total or Average	4,626	2,136	24,873	11,451	0.25	0.08	10.2	23.0	21.0	23.0	0.03	0.07

northern pike make up a large percentage of fish taken by spear. The data further show that spearing takes twice as many pike per hour as line fishing and tends to remove the larger pike. The catch per hour of pike is exceedingly slow by either method (average 0.03 pike per hour by line, 0.07 per hour by spear).

Reports from various sections of the state indicate that the change from five to two ice lines has affected the fishing in lakes containing pike. The tip-up seems to have been practically eliminated. Many former tip-up fishermen evidently took up spearing, and in addition operated two ice lines inside their shanties. Most complaints concerning the change in regulations (from two to five lines), came from fishermen frequenting lakes containing perch, pike and walleyes. The change in regulations particularly affected those who formerly fished with tip-ups for perch and walleyes since these species cannot be taken legally by spearing. The fish usually came slow with five tip-ups; two are not considered worth watching.

Number of lakes fished and number of fishermen: The number of lakes where winter fishing is practiced is small compared with the number fished in summer. Lakes not on or near the main travelled roads are seldom if ever visited by ice fishermen. Of twenty-eight lakes in the Waterloo Project area, ice fishing of any significance took place on only two during the past winter. The great majority of lakes in northern Michigan which are popular with the summer tourist are little if any fished in winter.

The total number of fishermen contacted during the intensive census on the six lakes which were checked by the C.C.C. was 13,077 in summer and 899 in winter, i. e., more than fourteen times the number of fishermen used the lakes in summer than in winter. The average number of ice fishermen per lake-acre on twenty-four lakes covered by intensive census (Table 3) was 0.2 as compared with an average of 4.8 fishermen per acre on the six lakes checked in summer.

Length of fishing day: The average number of hours spent on a lake by a fisherman seems to be inversely proportional to his luck. In winter when the catch per hour was low, fishermen spent, on the average, 3.6 hours; in summer the average "fisherman-day" was 3.0 hours.

Even though the fisherman-day is longer in winter than in summer, the effects of winter and summer fishing upon a lake are by no means balanced because of the smaller number of anglers in winter and the smaller catch per hour.

Species caught: In his papers on the fish catch in Fife Lake, the junior author (1935, 1936) has shown that most of the species which make up the bulk of the catch in summer, i. e., rock bass, bluegill, "smallmouth" bass, "largemouth" bass, walleyes, pumpkinseed sunfish and bullheads were rarely if ever caught in winter in this lake. In a pike lake such as Houghton Lake where walleyes, great northern pike

TABLE 2. COMPARISON OF RESULTS OF INTENSIVE CENSUS IN "SUMMER" AND "WINTER" ON SIX MICHIGAN LAKES

Lake	County	Area (acres)[1]	Period of census (days)	Ave. hours per fisherman-day	Fishermen contacted		Fish caught			Catch per acre[2]
					%[1]	No.	Total No.	Per hr.	Ave. size (inches)	
Fife	Gr. Traverse & Kalkaska	800								
Summer 1934			98	2.6	93	2,399	10,656	1.7	8.3	13.3
Winter '33-'34			entire season[3]	4.5	100	444	260	0.1	16.9	0.3
Summer 1935			98	2.5	98	3,594	11,375	1.3	8.1	14.2
Winter '35-'36			entire season	5.3	98	191	136	0.1	12.0	0.2
Budd	Clare	150								
Summer 1935			98	3.2	60	2,995	14,221	1.5	7.5	94.8
Winter '35-'36			entire season	...	100	none	...	...	...	...
Clear	Ogemaw	380								
Summer 1934			83	3.0	75	739	1,817	0.8	8.1	4.8
Winter '33-'34			entire season	3.8	100	63	108	0.45	9.7	0.3
Clear	Montmorency	160								
Summer '34-'35[4]			98	2.8	60	243	605	0.9	9.3	3.8
Winter '33-'34			entire season	4.0	100	28	164	1.5	7.4	1.0
Winter '34-'35			entire season	2.7	75	6	2	0.3	8.0	trace
Bear	Otsego	375								
Summer 1935			83	2.9	85	581	1,345	0.8	9.1	3.6
Winter '33-'34			entire season	1.5	100	6	...	...	...	...
Pleasant[5]	Oakland	86								
Summer 1935			98	4.2	95	2,526	10,095	1.0	7.7	117.4
Winter '35-'36			entire season	3.1	98	161	63	0.1	19.6	0.7
Ave. or total										
Summer		2,751	94	3.0	81	13,077	50,114	1.1	8.3	36.0
Winter		2,911	entire season	3.6	96	899	733	0.4	12.3	0.3

[1] Approximate.
[2] Catch per acre based on records for fishermen contacted only. The actual summer catch was considerably higher for some lakes.
[3] Entire season includes entire period lake was ice-covered (about 120 days).
[4] Summer data are for July 10-Sept. 30, 1934 and June 25-July 9, 1935.
[5] Census on Pleasant Lake taken by National Park Service camp, all others by M.E.C.W.

and yellow perch dominate the catch in both winter and summer and fishing is legal throughout the year, there may be a logical argument for some closed period. Whether this should be done by eliminating winter fishing, as has been suggested by some, is open to question.

The percentage of the total catch for the entire year and for the winter as made up for each of the ten species of warm water fish most caught, in the various districts of Michigan, is shown in Table 4. It will be noted from this table that yellow perch, great northern pike and suckers are the species taken most consistently over the state in winter. Except in districts 1 and 2, bluegills are taken little or not at all in winter even though they make up a good share of the catch in all districts for the year as a whole. The fish caught in winter are mainly predacious species; so that it may be possible that in most lakes summer fishing actually benefits by the removal in winter of a certain number of the larger pike, walleyes, perch and crappies—which if not so taken, would presumably keep down the supply of bass, bluegills, and other pan fish which usually make up the bulk of the catch in summer.

Average Size of Fish: The general census for 1935 indicates an average length of 9.0 inches for fish caught in summer as compared with 9.5 inches for winter caught fish. The averages for the intensive census are 8.3 inches by summer fishing and 12.3 inches by winter fishing.

The majority of lakes which were covered by the intensive census contained great northern pike or walleyes, and since these made up a greater proportion of the catch in winter than in summer, the discrepancy between these figures for the general and for the intensive censuses seems to be accounted for.

Catch per Hour: The number of legal fish taken per hour is an index to the *quality* of the fishing but tells us little concerning the *quantity* of fish removed unless a complete record of the "take" is secured as in the intensive census. The general census indicates that the catch per hour is higher in winter than in summer for four districts, the reverse in two others and equal for the seventh; the average for the two seasons being almost equal (1.7 fish per hour in winter, 1.6 fish per hour in summer).

Over a period of seven years, Conservation Officer Thomas White secured a record by random sample of 67,759 hours of fishing on Houghton Lake, our largest and one of our most productive "pike lakes." As in the general state census for 1935, the catch per hour in summer and winter in this particular lake was practically the same (0.36).

On many southern "bluegill" lakes the catch per hour at certain times in the winter may greatly exceed the catch per hour in summer. Conservation Officer C. G. Cole included six Branch County lakes in his general census returns for 1935. Records for these lakes indicated

TABLE 3. RESULTS OF INTENSIVE WINTER CENSUS ON EIGHTEEN ADDITIONAL LAKES

Lake	County	Area (acres)[1]	Period of census[2]	Ave. no. hrs. per fisherman-day	Fishermen contacted		Fish caught			Catch per acre[4]	Year
					%[3]	No.	No.	per hr.	ave. size		
Muskallonge	Montmorency	90	entire season	4.7	100	47	41	0.2	11.5	0.5	'33-'34
Hess	Newaygo	750	97 days	5.2	91.4	970	2,124	0.4	8.9	2.8	'33-'34
Round	Jackson	30	75 days	3.7	100	47	8	0.05	23.4	0.3	'33-'34
Wamplers	Jackson	800	75 days	5.5	96	716	402	0.1	19.2	0.5	'33-'34
Crescent	Oakland	150	69 days	3.0	100	335	162	0.2	10.6	1.1	'33-'34
Houghton	Roscommon	18,950	95 days	5.7	85	5,520	5,630	0.2	14.3	0.3	'35-'36
Lower Hamlin	Mason	3,100	59 days	3.9	75	377	420	0.3	11.0	0.1	'35-'36
Hubbard	Alcona	3,420[5]	81 days	4.2	98	215	262	0.3	11.7	0.1	'35-'36
Grand	Presque Isle	5,000	81 days	4.9	90	98	211	0.5	10.9	0.04	'35-'36
Long	Presque Isle and Alpena	4,600[6]	81 days	4.0	95	109	186	0.4	11.3	0.04	'35-'36
Ocqueoc	Presque Isle	320	entire season	...	100	none	...	...	...	...	'35-'36
Manistee	Kalkaska	845	96 days	5.0	100	125	52	0.1	20.0	0.06	'35-'36
Pickerel	Kalkaska	133	96 days	5.7	100	58	86	0.4	11.8	0.65	'35-'36
Higgins	Roscommon	9,600	74 days	3.8	100	365	785	0.6	10.2	0.1	'35-'36
Margrethe	Crawford	1,640	81 days	5.3	100	792	345	0.1	22.5	0.2	'35-'36
W. Twin	Montmorency	1,000	70 days	2.9	100	300	3,287	3.8	7.8	3.3	'35-'36
N. Manistique	Luce	2,000	77 days	3.8	99	117	1,552	3.5	8.3	0.8	'35-'36
Independence	Marquette	1,848	108 days	4.4	99	487	437	0.2	21.0	0.2	'35-'36
Total or Average[8]		57,187	.....	4.2	96	11,577	16,723	0.6	13.3	0.3[7]	....

[1] Areas taken primarily from Michigan Lake and Stream Directory and are only approximate.
[2] Entire season includes entire period the lake was ice-covered.
[3] Approximate percentage.
[4] Based on fishermen contacted during census period. For most lakes this figure would be slightly higher if records for all fishing for the entire season were available.
[5] Half of lake covered by census, area given above is half the area of the lake.
[6] 90% of lake covered by census, area given above is 90% of the area of the lake.
[7] Weighted average, other averages unweighted.
[8] Includes data for winter fishing as given in Table 2.

an average of 6.1 fish per hour, over 99% of which were bluegills. In spite of the increased winter fishing in these lakes in past years, the catch per hour in summer for 1935 in District 1 is second highest in the state (Table 5) and no complaints of depleted fishing in this region are heard.

As a result of severe winter-killing, it was possible last spring to get rough estimates of the population of fish in several southern Michigan lakes. Mr. Gerald P. Cooper of the Institute staff found that one lake had contained approximately 1,125 fish per acre of an average size of about six inches; another contained approximately 1,200 fish per acre of an average size of about seven inches. Forage fish, obnoxious fish, the fish which survived (if any), the dead fish which were not floating, and the fingerling food and game fish are not included in the above estimates. These data are, of course, too few to justify generalization, but there seems little reason to assume that the rich southern Michigan lakes are being seriously depleted of fish despite relatively intensive fishing during both winter and summer.

Our six lakes which were checked at both seasons yielded an average of 1.1 fish per hour in summer but only 0.4 fish per hour in winter. The average catch per hour on all twenty-four lakes checked in winter was 0.6. It is felt that this is a more accurate comparison of the catch per hour than can be secured from the general census because records for complete seasons were obtained so that the poor days and poor catches are represented as well as the poorer lakes.

Total Catch and Catch per Acre: Probably the most significant comparison of summer and winter fishing which can be made is of the actual per acre and total catch in lakes in the two seasons.

Summer fishing on the six lakes checked resulted in a total catch of 50,114 fish. Winter fishing on these same lakes (plus an additional winter for Clear Lake, Montmorency County) yielded 733 fish. In other words, more than sixty-eight times as many fish were removed in summer as in winter.

Considering the catch per acre for the average of these six lakes during these two seasons, the figures are even more impressive and probably more nearly correct. Summer fishing removed on the average 36.0 fish per acre; winter fishing 0.3 fish per acre. The effect of summer fishing was therefore 120 times as great as winter fishing. More fish were removed per acre during an average summer fishing day than were taken during the entire period of ice fishing. It is interesting to note (Table 3) that the average catch per acre for winter fishing of the twenty-four lakes checked was also 0.3 fish per acre, indicating that the six lakes compared directly for summer and winter fishing are quite representative in this important respect.

TABLE 4. PER CENT OF TOTAL FISH CATCH FOR WINTER AND FOR ENTIRE YEAR, FOR THE 10 MOST CAUGHT WARM-WATER FISH. GENERAL CENSUS, 1935, NON-TROUT WATERS ONLY. W=WINTER, Y=ENTIRE YEAR, TR.=TRACE.

District[1]	Largemouthed Bass		Smallmouthed Bass		Bluegills		Sunfis[2]		Perch		Walleyes		Northern Pike		Rock Bass		Sucker		Crappie[3]	
	W	Y	W	Y	W	Y	W	Y	W	Y	W	Y	W	Y	W	Y	W	Y	W	Y
1	tr.[4]	3	..	tr.	91	86	tr.	1	5	5	..	..	1	1	tr.	1	1	tr.	2	3
2	..	4	..	tr.	53	63	tr.	3	15	9	tr.	tr.	5	3	1	2	2	4	23	13
3	tr.	4	tr.[4]	1	3	43	tr.	3	86	29	tr.	1	3	1	tr.	7	1	1	6	9
4	tr.	2	..	2	4	18	1	12	75	34	4	5	12	8	tr.	16	4	1	..	1
5	..	1	..	3	..	7	tr.	6	93	49	1	11	5	9	..	13	1	1	..	..
6	..	7	..	2	..	39	..	4	..	16	..	tr.	5	4	..	10	95	3	..	17
8	..	10	..	20	..	13	..	3	43	23	13	13	43	7	..	3	..	1	..	..
Ave.	tr.	4	tr.	4	22	38	tr.	5	45	24	3	4	11	5	tr.	7	15	2	4	6

[1] District 7 omitted because of inadequate data.
[2] Primarily common sunfish (Eupomotis gibbosus).
[3] Mostly black crappie (Pomoxis sparoides).
[4] Caught and returned. Illegal to take bass in winter.

TABLE 8. COMPARISON OF HOURS FISHED, AVERAGE SIZE AND NUMBER OF FISH CAUGHT PER HOUR BY DISTRICTS. DATA FROM GENERAL CENSUS FOR 1935. (JANUARY, FEBRUARY, MARCH AND DECEMBER CONSIDERED WINTER FISHING; BALANCE SUMMER FISHING.)

District No.[1]	Season	Hours fishing reported	Fish taken	Average Size in inches	Fish per hour
1	Winter	2,055	5,898	7.7	2.9
	Summer	1,812	3,487	8.0	1.9
2	Winter	2,099	3,398	9.0	1.6
	Summer	4,744	7,414	8.2	1.6
3	Winter	3,269	8,167	7.4	2.5
	Summer	13,170	28,738	7.7	2.2
4	Winter	2,924	4,724	9.8	1.6
	Summer	6,287	8,835	8.0	1.4
5	Winter	726	1,444	7.4	2.0
	Summer	780	1,402	10.9	1.8
6	Winter	95	73	12,2	0.9
	Summer	2,631	4,191	8.4	1.6
8	Winter	181	106	12.9	0.6
	Summer	2,313	1,771	11.9	0.8
Average	Winter	1,621	3,402	9.5	1.7
	Summer	4,534	7,977	9.0	1.6

[1] District 7 was omitted because of insufficient data.

Summary and Conclusions

The evidence from creel census data may be summarized as follows:

1. Relatively few lakes are fished in winter as compared with summer, particularly in the northern part of the state.
2. Lakes are fished more heavily in summer than in winter although the average fisherman-day is slightly longer in winter.
3. The species caught in winter are mainly limited to predacious fish such as pike, walleyes, perch and to coarse species represented by the suckers. Except in the extreme southern part of the state bluegills are not taken in numbers.
4. Winter fishing, especially by spear tends to remove the larger sizes of pike.
5. The number of fish taken per hour is much lower in winter than in summer on lakes where intensive census was carried on. The number of bluegills per hour may be higher in southern lakes on certain days in winter than in summer, but the general census does not indicate any decline in the catch per hour.
6. The total winter catch and catch per acre is much less than in summer.

On the basis of this evidence it is concluded that winter fishing is not generally harmful to summer fishing in Michigan. In "pike lakes" such as Houghton Lake a closed period to protect the great northern pike and walleyes during the spawning season seems more justifiable

than eliminating the sport of winter fishing. When sportsmanlike methods are employed, ice fishing may furnish fully as much and as valuable recreation as does summer fishing, and is deserving of equal consideration.

Figure 1. General census districts.

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FISH MOVEMENT UNDER THE ICE IN AN IOWA LAKE

W. W. Aitken

Chief Biologist, Iowa Conservation Commission, Des Moines, Iowa

In an effort to secure information regarding feeding and pre-spawning habits, oxygen requirements, population ratios, migration, and other phases of fish life during the winter months, a preliminary study was made in the winter of 1935-36 at West Okoboji, Dickinson County, Iowa, as the first of a series of similar studies to be conducted each winter on this and other areas of the state.

Few ecological studies have been made on West Okoboji for any definite period. However, Stromsten of Iowa made a noteworthy study of thermoclines extending over a five year period. Larrabee in 1926 described the fishes of this region. Hubbs in 1932 made certain studies of this lake. The Lakeside Laboratory of the State University of Iowa has been engaged a number of years during the summer months in investigating some of the biotic factors connected with this lake and surrounding region.

West Okoboji has a surface area of 3,939 acres and ranges up to 132 feet in depth. When this study was made, the lake was solidly frozen over all winter and covered during this period with a heavy blanket of snow; no seams opened at any time, a very unusual circumstance.

For the past 20 years, gill-netting through the ice under State jurisdiction has been permitted at this lake. The purpose has been to reduce the population of carp and buffalo. Gill-nets used have a four-inch bar mesh, eight to twelve feet deep and are not more than 200 feet long. Each fisherman is restricted to three nets, each net not exceeding the standard length. Each gill-netter selects his own fishing site, and usually builds a rough board or sheet-metal shack over his net hole. The nets are extended in opposite directions from the shack. This arrangement permits the fisherman to lift all his nets through one hole.

As the fishermen locate more or less uniformly over the lake surface and because they are required by the Conservation Commission to lift the nets daily and make a daily report of catch, it was thought to be an opportune occasion to secure pertinent information concerning fish life in a lake during a period when physical conditions prevented ready ecological study. The observations and records were kept over a 90-day period, the length of time fishing was permitted. Daily catch report forms were furnished each fisherman, checked daily, and collected by the State Supervisor of the gill-netting. The daily record showed temperature, weather conditions, and water depth. Oxygen and pH. tests were made from time to time in each area. All fish were weighed and counted by the Supervisor.

The lake was divided into five zones, as shown on the map, in

order that a comparison might be made of concerted fish activity in the different areas, such as movement that might come from seams opening, activity through current changes at proximity to inlets and outlets, effect oxygen depletion might have on fish movement and effect of cloudiness or other weather changes on fish under the ice. By zoning the lake, some correlation might also be noted in fish movement in bays with differences in depth, amount of vegetation present, volume of oxygen, and chemical conditions.

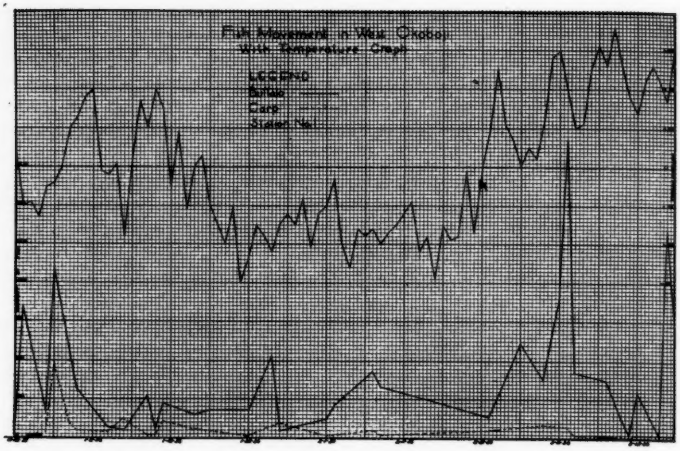
Graphs were made showing the movement in all zones; however, only two of the more typical are here shown, with an additional graph of an individual fisherman taken at random from the group. The temperature reading is included on the graph for Station One, to show that there is some correlation between outside temperature and movement of fish under the ice.

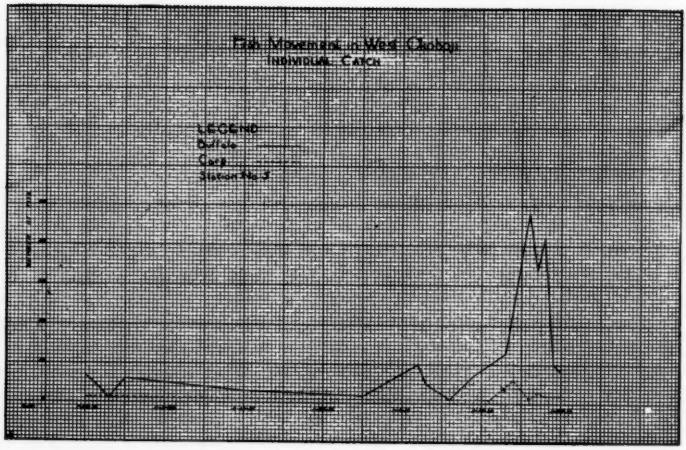
The conclusions offered are not to be considered a prediction of what may be shown in next year's study of the same area as the past winter was described by the U. S. Weather Bureau officials as the most severe northern Iowa experienced over a period of 117 years.

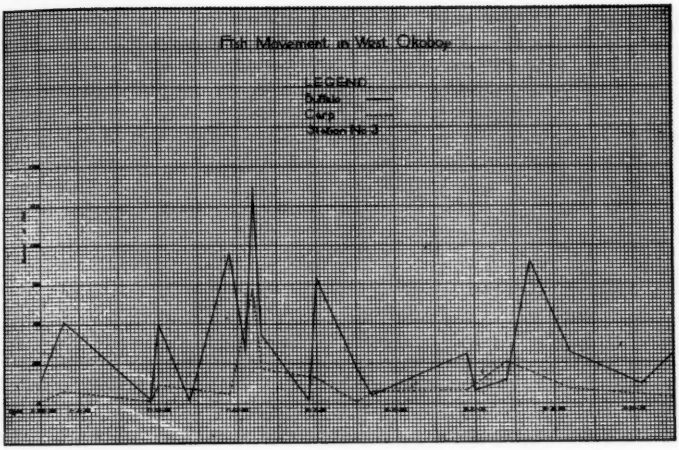
Station One is that area of the lake where the inlet and outlet are located. Here the water ranges to thirty feet deep and because of possible unusual water currents here, fish movement was expected to be quite different than in other areas. However, less movement by large numbers of fish was evidenced here. The carp and buffalo movement was comparable in relation to time of activity, but not in relation to numbers. The temperature graph shows a definite correlation between rise and fall of temperatures and concerted movement of fish. A study of the other areas, in respect to temperatures, shows this more or less held true for the rest of the lake.

At Station Two, fluctuation in fish movement seemed to be more pronounced than at other stations. It is concluded that this phenomenon was due to the larger area and deeper water, as this area is the deep "hole" of the lake. At this station buffalo movement was quite pronounced and carp movement, at times, did not match buffalo migration.

At Station Three, where many of the fishermen operated, the water was from five to ten feet deep and in this shallower water carp movement was more evident than in deeper areas fished at the same station. It is concluded that a greater number of carp inhabit shallower water in the winter than do buffalo. It is also concluded that the buffalo are more active than carp in the deeper water. Because buffalo and carp movement here very closely approximated fish movement at Station Two it is considered evidence that overhead weather may influence fish movement. Other factors mentioned, convection currents, escaping gases and noises attending ice disturbances, that one would expect to influence fish movement were eliminated by the complete sealing of the lake.


Fish Movement in West Okobo
with Temperature Chart
LEGEND
Buffalo
Carp
Station No.1


Fish Movement in West Okobo
INDIVIDUAL CATCH
LEGEND
Buffalo
Carp
Station No.5



Movement was also typical at Station Four for the early part of the winter but during the more severe part of the winter all fish movement was slight. This was no doubt due to low oxygen conditions that hit this area the latter half of the winter.

In the graph showing the single fisherman results, a definite quiescence of both carp and buffalo is evidenced throughout the period when the mercury was lowest. As overhead weather modified, fish movement again took place.

At all stations, as warmer weather approached in late March, fish movement definitely became more evident. It is also noted that in a study of rise and fall of temperature that movement of both carp and buffalo was correlated with temperature raise and definite group movement ceased as the mercury fell.

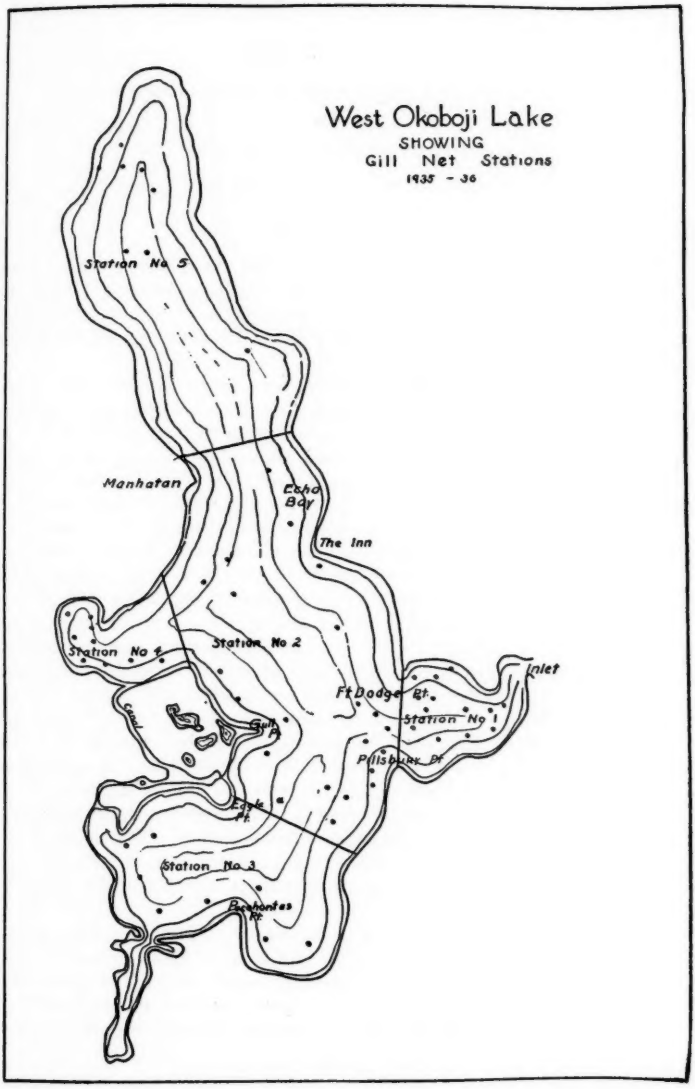
In a tabulation of buffalo movement in clear weather in opposition to stormy weather, a ratio of five to one occurred favoring greater activity when overhead weather was clear. There was only a slight difference in carp movement noted during clear or stormy weather with a slight tendency for greater activity when weather was clear.

In the graph showing both temperature and fish movement, the period of extreme low temperature shows a marked inactivity of both buffalo and carp. It is also noted in all graphs that in the majority of cases carp and buffalo moved simultaneously which would indicate a fundamental stimulus affected fish without regard to particular species. This factor may be atmospheric pressures or light intensity.

The total number of fish taken in this study was 7,939 buffalo and 1,154 carp, showing a preponderance of buffalo in a ratio of nearly seven to one. The average size of the carp exceeded that of the buffalo; the carp average size was 8.89 pounds, the buffalo 6.17 pounds. These figures show that buffalo, as a class, are smaller fish than carp, or that smaller carp are not as active as larger carp in winter months, or that smaller buffalo are more active than larger fish of this species.

Very few game fish were caught. The total catch for the entire lake was twenty pike-perch, sixteen sheepshead, one catfish, three northern pike and one silver bass. These fish were, of course, too large to swim through a four-inch bar mesh. Because of the large mesh there is no way to determine the movement of these smaller species or of small buffalo and carp.

A continuation of this study will be made and card files kept of all factors noted and considered. Acknowledgment is made of the co-operation of the Fisheries Division in collecting these data, particularly that of Mr. Ray Butler of Arnolds Park, Iowa.


West Okoboji Lake
SHOWING
Gill Net Stations
1935 - 36
Station No 5
Manhatan
Echo Bay
The Inn
Station No 4
Station No 2
Inlet
Ft Dodge Pt
Station No 1
Pillsbury Pt
Station No 3

SOME OBSERVATIONS ON MINNESOTA FISH PONDS

THADDEUS SURBER

Department of Conservation, St. Paul, Minnesota

AND

THEODORE A. OLSON

State Board of Health, St. Paul, Minnesota

INTRODUCTION

Pond fish-culture is a relatively recent thing in this country, although it has long been practiced, especially with reference to rough fish in the European countries. In recent years the culture of certain game fishes in ponds has assumed an important rôle in the program of fish propagation.

Pond culture is reserved, of course, for species whose eggs cannot be satisfactorily hatched by artificial means, such as crappies, sunfishes, catfishes and the basses, which must be permitted to make their own nests where eggs may be fertilized and allowed to develop in a natural way. The number of adult fishes that may be placed in an artificial pond will vary with the species, each having its own maximum concentration point beyond which it is inadvisable to go. The function of the pond is to produce sustenance for an abnormally concentrated number of young fish for a short period until they are large enough to be distributed safely to other waters where there is more room and food. The pond, in short, should provide a sheltered and protected environment rich in food suitable for young fishes until they are large enough to take their place successfully in the less sheltered natural environment.

It has been the general feeling that continued sport fishing has depleted our waters of a considerable quantity of the fish life that they should be able to support, and that nature should be aided in replenishing the loss. As a result, numerous areas within lakes have been set aside as spawning beds, and ponds or series of ponds have been constructed for the propagation of fishes. The species most commonly selected for pond culture in this northern section of the country is the black bass. The popularity of the bass as a game fish and the growing interest in matters pertaining to conservation have brought about the construction of many bass ponds.

Some of these ponds have been created by damming small streams and flooding additional territory with extensive shallow areas in which vegetation and fish food may be produced and where the fishes may build their nests. Other ponds have been constructed artificially in various ways. The water is usually supplied through the diversion of

a stream or part of a stream, by flowing wells or springs, or by water pumped from surface or underground sources. Some ponds have been very productive yielding almost phenomenal numbers of fingerling bass yearly. Others have been relatively unproductive, although, to all general appearances, living conditions were identical to those in the productive ponds.

In Minnesota a number of bass ponds, some productive, others almost barren of results, have been constructed during the last few years. In an attempt to determine a possible reason for the lack of success one of the unproductive ponds was selected for a study of the chemical composition of its water and its plankton production. For the purpose of making comparisons two other bass ponds and a small lake were studied simultaneously. The four bodies of water involved will be designated here as ponds A, B, C and D. Pond A (See Table 9) was constructed artifically and is fed by water diverted from a small river. Pond B is an exceptionally productive artificial pond with a spring-fed brook for its water supply. Pond C was formed by damming a small creek which flows through a large swampy area before it enters the pond itself. Pond D is generally considered a lake, although it is quite shallow and the longest dimension is less than three-fourths of a mile. This lake has been very productive and large numbers of pike, all showing extremely rapid growth, have been taken from it soon after planting. There is no inlet or outlet to pond D, the level of which is therefore dependent upon the local run-off from rains and possibly on springs in the lake itself.

One of the important factors that determine the productiveness of a body of water inasfar as fish life is concerned is the availability of food. The forage problem is far less simple in water than it is on land and much is yet to be learned concerning this subject. Our best food and game fishes are carnivorous after they have passed their early stages of life, feeding most commonly on the larger plankton crustacea and insect larvae, and some species when well grown shift their diet almost entirely to other fishes.

The ultimate source of fish food, however, is the vegetation produced in the water, and although the larger aquatic plants are at once brought to mind when vegetation is mentioned, this term also includes that minute free-floating assemblage of plant organisms commonly known as phytoplankton. In fact, it is now well established that the plankton organisms, a term including both animal and plant organisms of minute size, are one of the most important factors in fish production. The types of organisms that occur in the plankton may vary with the locality and the season. There is often a rapid succession of crops, one succeeding the other, but unlike field crops this productivity extends even to the coldest winter months. The winter crops are usually less bountiful however.

Although the young of all fishes are plankton feeders, the plankton

organisms are not always suitable as food for the adults. The food of most adult carnivorous fishes consists chiefly of entomostraca, insect larvae and nymphs, small molluscs, and certain forage fishes, all of which derive the greatest part of their nutriment from the plankton. This relationship still points to planktonts as the ultimate food organisms. Bajkov (1930) stated that the alimentary tract of different species of bottom organisms which serve as food for the whitefish in certain Manitoban lakes, contained living as well as dead plankton forms. In deeper areas of the lakes an uninterrupted rain of these plankton organisms kept the bottom dwellers, alive, even though they were far removed from the productive layers near the surface.

In a study of the productivity of a fish pond, therefore, we are interested in the plankton production rather than the total plant growth. The results of quantitative studies on the larger plankton or net plankton forms and on the smaller or centrifuged plankton of the ponds discussed here, are presented in this paper. The samples do not represent a long, continuous series, but do indicate the conditions existing in winter, late summer and fall in each pond.

The growth of phytoplankton and large vegetation is dependent upon the presence of carbon dioxide and sunlight, necessary for photosynthesis, and on elements such as nitrogen, phosphorus, potassium, etc., which are necessary to build up the plant tissues. The necessary elements also include those which may not directly become a part of the plant tissue but whose presence is necessary to promote growth. If one of the needed elements is depleted, it becomes a limiting factor and plant production is influenced by it. A chemical analysis of the water will therefore supply information relative to its capacity to produce fish food. The results of chemical analyses presented in this paper are derived from a total of some thirty determinations, including the determination of five forms of nitrogen. Three sets of these samples were collected for analysis at each pond, and each was collected at the same time as corresponding plankton samples.

The measure of food production in the fish ponds considered here is based on counts of the numbers of organisms in the centrifuged and net plankton samples. A centrifuged plankton sample is obtained by passing two liters of water through a continuous electric centrifuge of the Foerst type. Net plankton samples are taken by pouring 100 liters of water through a number twenty-five silk bolting cloth net. The results are expressed in the centrifuged samples as the number of organisms per liter of water, and in the net plankton as the number in each hundred liters.

The methods outlined in the Standard Methods of Water Analysis, published by the American Public Health Association (1933), were followed for all except the phosphorus determinations. The phosphorus determinations, however, were based on the method described by Juday, *et al.* (1928), and Titus and Meloche (1931). In using this method

it was found that some sulphuric acid still remained after the digestion, and that its presence could effect the color comparison. The method was therefore modified to compensate for this reaction.* Except for determinations such as pH or temperature, results are always expressed in parts per million. Determinations such as color and turbidity are expressed as parts per million in terms prescribed by the standard methods of procedure mentioned above.

Nitrite, pH and dissolved oxygen determinations were made in the field immediately following the collection of the sample. The determination of the various forms of nitrogen exclusive of the nitrite just mentioned, was begun within three hours of the collection of the sample, in order that there should be as little opportunity as possible for change or loss of these relatively unstable substances. Other determinations were not rushed in this manner, however.

Samples were collected from each of the four ponds late in the fall of 1933, and during the winter and late summer of 1934. The first plankton and chemical samples were collected from pond C, October 31, 1933, and from ponds A, B and D on November 1, 2 and 3 respectively. Winter samples were collected during the first part of February, and the later summer samples in the early part of August. The exact dates for these collections are given in Table 1. With the exception of August 9, only one pond was visited each day for the reason that the ponds were far apart and some distance from the laboratory. The need for immediate attention inasfar as nitrogen determinations were concerned also limited the number of samples which could be handled at one time.

Physical and Chemical Analyses

Dissolved Oxygen: The dissolved oxygen data are presented in Table 1, which also includes a summary of all the other chemical determinations. The oxygen content of the water, it will be noted, was very low during the winter period in ponds A and C. The result recorded for pond C does not represent the lowest observed, however, for in additional investigations of the dissolved oxygen in this pond, it has been found that the oxygen may be entirely depleted during the late winter months. In connection with other investigations pond D has also been observed to have a lower oxygen in late winter than recorded here, but entire depletion has not been observed. Pond B, in contrast to the other ponds observed, had a consistently high oxygen content. In February, pond B was supersaturated with oxygen (166 per cent or 21.2 parts per million), while the other ponds varied from 1.4 to 4.5 parts per million.

In August, the water level of pond C had been lowered about three feet, and it had become choked with large aquatics (chiefly *Ceratophyllum*). In addition, its surface was covered with duckweed which so

*Modified method worked out by Mr. Dean Taylor of the Division of Sanitation, Minnesota State Board of Health, in making the analysis here described.

shaded the underlying water that oxygen producing plants did not receive light. As a result, although fresh water was running into the pond, the water at the outlet was entirely depleted of oxygen. The other ponds visited during the same period contained an ample supply, even though the temperature of the water stood at 26°C.

The greatest range in the oxygen content of these ponds occurred in pond C where it varied from 153 per cent saturation in October, 1933, to entire depletion in late winter and August of the next year. Pond B had a high dissolved oxygen concentration at each sampling period, the lowest amount representing a saturation of 92 per cent. The low oxygen concentration in pond A in February was undoubtedly brought about in part by the effect of the water supply. At this time the entire volume of water flowing into the pond came from an artesian well, the water of which was entirely devoid of dissolved oxygen, even at the point where the water entered the pond. A bloom of chlorophyll-bearing Mastigophora and green algae which occurred at this time was probably the principal agency in raising the oxygen content of the inflowing water to the 1.4 parts per million observed in the ice-covered pond.

pH: The pH varied to a limited degree only. The total range of fluctuation was from 7.7 to 8.3 or entirely within the alkaline range of the pH scale.

Five-day Biochemical Oxygen Demand: The oxygen demand varied from 1.4 parts per million to 6.7 parts per million. The mean for all determinations was 3.2 parts per million. The highest figure was obtained for pond A in February, when the oxygen content was lowest and the dissolved volatile matter and plankton content were highest. The combined effect of this oxygen demand and the low dissolved oxygen content of the inflowing water led to a serious oxygen depletion in spite of the presence of an algal bloom. The algae might otherwise have increased the oxygen through photosynthetic activity. As a whole, however, the oxygen demand was relatively low in all the ponds and could not by itself be classed a factor limiting productivity.

Color: The color of the water was moderate. Pond B had the least color, with a minimum of less than five and a maximum of twenty parts per million. Pond A had the highest color reading, namely, fifty parts per million. In view of the shallowness of the ponds this amount of color is probably of small importance as a factor in limiting photosynthesis.

Turbidity: The turbidity was very low in ponds B and C, ranging from 1.2 to 3 parts per million. Ponds A and D had somewhat higher turbidities, the highest being 23.0 parts per million in pond A. In these two ponds the turbidity was low, except at times when algae were very abundant. For instance, in pond A the highest turbidity

occurred at a time when there were more than five million plankton organisms per liter of water, while there were less than 400 thousand organisms per liter when the turbidity reading was 6. The high turbidity, therefore, was not a limiting factor in this pond, but, on the contrary, was a result of high productivity.

Solids and Volatile Matter: The total solids of the water in the ponds were fairly high. The range was from 159 parts per million in pond B to 838 parts per million, the maximum, in pond A. Bajkov (1930), in his tabulations of the chemical analyses of water from Lake Winnipeg and connecting waters, recorded total solids ranging from 40 to 640 parts per million. A single sample of water from Lake Winnipegosis contained 1,265 parts per million total solids. Analyses of water from the Minnesota ponds showed that the bulk of the total solids consisted of dissolved matter. The data of Table 1 show that dissolved solids ran as high as 822 parts per million. The dissolved volatile matter, sometimes referred to as dissolved organic matter, although it also includes volatile decomposition products from carbonates, nitrates and other residue compounds, ranged from 114 parts per million in Pond B to 285 parts per million in pond A. Pearsall (1921) reported on the dissolved solids of English lake waters. His results were only about one-tenth as high as the results reported here. He found total dissolved solids to vary from 30.6 to 75.9 parts per million, and the organic dissolved solids, apparently comparable to our dissolved volatile solids, to run from 2.4 to 13.8 parts per million, with a mean of 8.3 parts per million. These results resemble those obtained in this country for bodies of water such as Lake Superior where the total solids are about 50 or 60 parts per million.

In general, the suspended solids were relatively low in the bass ponds, and there seemed to be no good correlation with plankton counts. Total solids were highest in pond A, and lowest in D although there was very little difference in the average results for ponds B, C and D.

Alkalinity and Hardness: Hardness and alkalinity are both expressed in terms of $CaCO_3$. The calcium and magnesium equivalent in $CaCO_3$ is the usual measure of the total hardness of a water. Iron and aluminum are also included although they are to a less extent responsible for the condition commonly called "hard water." Alkalinity represents the content of carbonates, bicarbonates, and hydroxides and occasionally borates, silicates, and phosphates in natural waters. The relationship of alkalinity to different indicators is such that the results may be reported in terms of $CaCO_3$ and on the basis of the reaction to the indicators used, as normal carbonate, bicarbonate, or hydroxide. Since there was no phenolphthalein alkalinity in the Minnesota ponds, the alkalinity was all due to bicarbonates. The alkalinity ranged from 66 parts per million in pond B to 488 in pond A. The late summer samples in ponds A, B and C had a slightly lower total alkalinity than

samples taken at other times. The total hardness closely approximated the total alkalinity, but was usually a trifle higher, however. The excess by which total hardness exceeds carbonate and bicarbonate alkalinity, is known as noncarbonate hardness. On this basis, the values for noncarbonate hardness* varied from zero to 75 parts per million and the average of pond B, which was highest, was 69 parts per million. The figures in Table 1 indicate that pond D has a consistently lower hardness and alkalinity than the other ponds. The average total hardness in D was 156 parts per million whereas the other ponds each averaged more than 200 parts per million. Excluding small variations, these ponds are somewhat similar with reference to alkalinity and total hardness. With reference to other bodies of water they may be referred to as hard or moderately hard. Bajkov (1930) reported the $CaCO_3$ alkalinity of certain Canadian lakes as varying from 138 to 324 parts per million. These figures are near those given here. Pearsall (1930) on the other hand found a carbonate hardness range of only 0.5 to 15.7 parts per million in nine English lakes. From the foregoing, it is readily seen that natural waters may have a great range in alkalinity and hardness. Soft-water lakes, such as the English lakes, are not usually as productive as the hard-water lakes.

Chlorine, Iron, Manganese and Aluminum: These elements are not usually considered of extreme importance, yet they may have some effect in connection with other substances upon the productivity of a body of water. The chlorides varied from 0.5 parts per million in pond C to 8.0 in ponds A and B. The results were most uniform in pond B where the average was 6.8 parts per million. These figures are fairly low. Bajkov (1930) reported values for chlorides that ranged from zero to 85 parts per million for Lake Winnipeg and connecting waters.

Iron was present at all times in moderate amount ranging from 0.05 parts per million to 0.7 parts per million. This is less than the amount reported by Bajkov for Canadian waters, where iron was present in quantities from 0.1 to 3.5 parts per million. In the English lakes, however, the range was from 0.008 to 0.3 parts per million only. (Pearsall 1930)

Manganese was absent in pond B in August 1934, but was present in all other determinations as a trace or more. The maximum was 0.35 parts per million in pond A. Wiebe (1930) reported 0.044 to 0.120 parts per million manganese in Mississippi River water.

The aluminum content was highest in Pond A and lowest in Pond B. The range was from 0.11 to 7.18 parts per million. There seems to be no regular seasonal change. In Pond D, the aluminum content was almost as low as in B except in August when it rose to 4.4 parts per million.

*Based on the total hardness as determined by the soda reagent method.

Calcium, Magnesium, Potassium and Sodium: The $\frac{\text{potassium plus sodium}}{\text{calcium plus magnesium}}$ ratio was very low indicating that on the basis of Pearsall's (1922) classification these ponds are typically calcareous. In pond A, for example, the results of the first analysis of these four elements may be expressed numerically as $\frac{10.7}{94.7}$. The calcium content of the water in these ponds was fairly high reaching a maximum of 136 parts per million in Pond A. Magnesium was lower in concentration, the highest being 35 parts per million. The calcium was lower in the August samples from ponds A, B, and C than at other periods. Pond D showed the least variation in magnesium and calcium and had the lowest concentrations of these elements. Bajkov's results for Canadian waters ranged from 6.0 to 80 parts per million for Ca and from a trace to 40.3 parts per million for magnesium. His average for calcium was somewhat less than figures presented here*, but the magnesium average was almost the same.

Potassium and sodium are given together as sodium in all except the last set of determinations. It will be seen that there was considerable variation in the results. The total varied from 1.9 parts per million to 41.6 parts per million. The highest concentrations occurred in pond A and the lowest in B. This difference may be a result of the water supply in the ponds. Pond B as earlier stated is fed by a brook which originates in springs only a short distance from the pond while pond A for a considerable part of the year receives its supply from a river running through cultivated country. In the August analyses, sodium exceeded potassium in ponds A, B and C, but in pond D the amount of potassium was slightly greater. Bajkov found a sodium and potassium total of 91 parts per million for the Red River at River Park, Manitoba, but the average was much below this figure. Pearsall (1921) reporting these elements as Na_2O and K_2O found that the mean in the English lakes was 10.6 parts per million. The mean in the bass ponds expressed as sodium and potassium and not as the oxide was 16 parts per million.

Insoluble Sulphides and Sulphates: The test for insoluble sulphides was negative in every determination. Sulphates ranged from 9.78 to 109 parts per million. The mean sulphate content of water in pond A was 71 parts per million and in pond D, 17 parts per million. Except-

*Bajkov's (1930) average Ca was 37 parts per million. Ca in fish ponds reported here averaged 56 parts per million.

ing in pond A, there seemed to be a tendency for a reduced sulphate content in late summer samples.

Silica: The total range of silica (expressed as SiO_2) in these analyses extended from 12.5 to 29.8 parts per million. The mean was 23 parts per million. There was no general agreement in the time of variation of silica in the various ponds. Ponds A and C, however, had their maxima in February. This observation agrees with results obtained by Yoshimura (1930) who found in Takasuka Pond a minimum of 6.3 parts per million in July and a maximum of 13.1 parts per million in February. In ten Japanese lakes the silica content ranged from 2.3 to 27.3 parts per million. These results and the results of Bajkov (1930) for the Canadian lakes, covering a range from 1.8 to 36 parts per million, are comparable with those of this study. Pearsall's (1930) determinations on the other hand, were much lower. That author found SiO_2 in English lakes to range from 0.1 to 2.4. The concentration of silica found in the Minnesota fish ponds was never near the minimum of 0.5 parts per million tentatively suggested by Pearsall (1932) as the lower limit for diatoms.

Phosphorus: Phosphorus is expressed here as phosphate phosphorus and was determined as soluble, organic, and total phosphate. Soluble phosphate was present only as a trace in ponds A and C in the fall of 1933, and may have served as a limiting factor to further plankton production at that time. In ponds B, C and D the highest concentration of soluble phosphate occurred in the late summer samples. In pond A, the results for late summer and for winter were nearly the same. In all ponds the soluble phosphate ranged from a trace to 1.223 parts per million.

Organic phosphate was most abundant in ponds A, C and D during the fall (the last part of October and the first part of November), but in pond B the organic phosphate was most abundant in February. These results do not agree with those of Tressler and Domogalla and others with respect to seasonal distribution. However, results obtained by Juday and Birge (1931) were not consistent either, for in a series of fifty-four pairs of phosphorus determinations they found sixteen pairs which yielded larger amounts of soluble phosphorus in summer than in spring. It is possible that differences in results may be caused by some change in some of the samples soon after collection and before the analysis has been made.

The total phosphate varied from 0.0765 to 1.223 parts per million. Pond D had the greatest phosphate concentration and the mean for this pond was 0.846 parts per million. The mean phosphate concentrations for ponds A, C and B in the order named were 0.2959, 0.1921 and 0.0920 parts per million. The maximum recorded by Pearsall (1930) was 0.04 parts per million phosphate phosphorus. The minimum obtained for the fish ponds is almost 100 per cent greater than this figure. Yoshimura

(1932) in defining productive lakes in Japan, set up as the most productive type a lake with 0.1 part per million phosphate and as a mesotype, one with 0.05 to 0.1 part per million phosphate. If the means of the soluble phosphorus and of the organic phosphorus obtained by Juday and Birge (1931), are added and expressed as phosphate, the mean of the total phosphates in Wisconsin lakes is 0.07 parts per million. It is evident from the foregoing that the phosphate content of the Minnesota pond waters compares favorably with productive waters elsewhere. It is true that soluble phosphate was observed to be reduced to a trace in two ponds and such a reduction may effect productivity. It is to be expected, however, that a temporary depletion would soon be relieved in shallow ponds of this type through conversion of organic phosphate to the soluble form. This conversion will occur unless the organic phosphorus is entirely tied up in living organisms.

Nitrogen: The nitrogen content of the fish-pond waters was fairly high. The mean of the total nitrogen was 2.984 parts per million and the minimum 0.853 parts per million. Nitrate nitrogen varied from 0.078 to 4.5 parts per million. These results are very high compared to Pearsall's results from the English lakes (1930). Pearsall found only 0.005 to 0.20 parts per million of nitrate nitrogen. Domogalla and others (1925) reported that soluble nitrogen, which includes more than nitrate nitrogen, in Lake Mendota varied from 0.3804 to 1.7392 parts per million. Results from twelve other Wisconsin lakes were lower. Yoshimura (1930) gave 0.2 parts per million nitrogen as the upper limit in the productive type of Japanese lakes.

It is generally conceded that usually inorganic nitrogen (ammonia and nitrate) increases markedly in February or March and that the concentration of organic nitrogen is usually inversely proportional to that of inorganic nitrogen. In ponds B and C, these conditions obtained, but not in ponds A and D. In the latter ponds organic nitrogen was generally higher than the inorganic nitrogen and in pond D the inorganic nitrogen followed the organic nitrogen instead of being inversely proportional to it. In pond A the organic nitrogen reached a high point in February while the inorganic nitrogen dropped slightly. A marked bloom of algae was undoubtedly responsible for the high winter concentration of organic nitrogen inasmuch as the determination here included the plankton nitrogen. Organic nitrogen was higher than the inorganic nitrogen on each occasion that samples were taken in pond A. Pond A also had the highest organic nitrogen concentration of any of the ponds, and B the lowest. The averages for ponds A, D, C and B, respectively were 2.02, 1.66, 0.660 and 0.536 parts per million.

The mean nitrogen concentrations in ponds A and D were highest and in B and C were next in the order named. Nitrate nitrogen was highest in pond B and lowest in pond C. Ammonia nitrogen was highest in pond A and lowest in pond B. It is probable that an abundance of oxygen at all times in pond B permits the change from ammonia to

nitrate to take place more rapidly than in the other ponds, which have been observed to be low in oxygen at times. Therefore, although inorganic nitrogen is high in pond B only a small part of it is found as ammonia or nitrate.

Plankton

Centrifuge Plankton: The smaller and more abundant types of planktonts are included in samples concentrated by means of the centrifuge and the total number of organisms enumerated may often be large. The number of organisms varied from 113,000 per liter in pond C to more than ten million per liter in pond A. A comparison of results at each sampling period showed that pond A had the largest number of plankton organisms in November and February while pond D had the greatest number in August. The mean for each pond ranged from 260,000 per liter in pond C to 5,691,000 per liter in pond A. The means for ponds B and D which were similar in productiveness exceeded half a million organisms per liter.

Pond A: In the November collection diatoms were predominant, *Cyclotella* the most important form. Flagellates represented by *Trachelomonas* and *Chlamydomonas* were also very abundant.

In February the flagellates and green algae were the dominant groups. *Volvocales* spp. and *Ankistrodesmus falcatus* were the important organisms and their abundance was such that they were visible to the naked eye as a "water bloom."

Total plankton numbers were much lower in the August collection than in those preceding it. *Chlamydomonas* was the most abundant form and diatoms were next in importance.

Pond B: In this pond as in pond A, diatoms were predominant in November. *Cyclotella, Navicula* and *Synedra* were the important genera. In point of numbers green algae were next to the diatoms in importance. *Ankistrodesmus falcatus* was the most abundant species in this group.

The February sample was characterized by a continued predominance of the same types of diatoms which had appeared in the fall collection. Green algae, however, had practically disappeared and the Mastigophora had increased markedly.

In August the Mastigophora consisting chiefly of *Chlamydomonas* spp. and *Trachelomonas* spp. formed the bulk of the plankton. Diatoms consisting principally of *Navicula* and *Gomphonema* were second in abundance. Blue-green algae were present in moderate numbers.

Pond C: Plankton organisms were relatively scarce in the November sample. With the exception of diatoms which were the dominant forms, there were few organisms represented. *Cyclotella, Navicula* and *Cocconeis* were the important diatoms.

In February the blue-green alga, *Lyngbya,* was predominant. Diatoms were much reduced in abundance and the principal species at this time was *Synedra tenuissima* instead of *Cyclotella* or *Navicula.*

Diatoms were again predominant in August. *Homoeocladia amphibia* and *Navicula* spp. were most numerous. Mastigophora were also abundant and *Chlamydomonas* was the most important form.

Pond D: In late fall this pond was characterized by an abundance of diatoms, in winter by green algae and in late summer by blue-green algae. The total number of organisms was fairly low except in the late summer samples.

In November *Cyclotella* and *Cocconeis* were the important components of the plankton. In February, however, *Ankistrodesmus falcatus,* a green alga, outnumbered all other forms, while the August collection contained *Lyngbya* and *Anabena* primarily. In August the blue-green algae formed a definite "bloom."

Net Plankton: The net plankton includes principally the organisms such as Copepoda, Cladocera, Rotifera and large protozoans. These are organisms of sufficient size to be retained by the meshes of a number twenty-five silk bolting-cloth net, but which are not abundant enough to permit accurate enumeration in the smaller centrifuged samples. Some of these, especially the crustaceans and rotifers are important elements of fish food.

The range of abundance of net plankton forms was from fifty organisms per 100 liters in pond C in February to 187,670 per 100 liters in pond D during August. The average for each pond ranged from 6,250 organisms per 100 liters to more than 85,000 per 100 liters. Pond A had the highest and pond C the lowest number of net plankton forms.

If only cladocerans, copepods and rotifers are considered, the ponds, as named in order of the greatest abundance of organisms reached in each, are B, A, D and C. Pond A, however, seemed to have a more uniform productiveness than the other ponds.

The maximum abundance per 100 liters reached by the various organisms was 73,216 for Copepods and 25,344 for Cladocera (pond B) and 60,732 for rotifers (pond A).

Although comparison of results from a small number of samples with those from more extensive surveys may not be entirely justified, they do serve as a means of orientation. For instance, Wiebe *et al.* (1929) found that Crustacea, excluding nauplii, averaged 26,570 organisms per 100 liters in a control pond which was unfertilized. In the Minnesota ponds described here the highest average was 18,479 organisms per liter (pond B).

Bosmina obtusirostris was the most common form among the Cladocera, and *Cyclops bicuspidatus* and *Cyclops serrulatus* among the Copepoda. More than twenty species of rotifers were identified. *Keratella cochlearis* was one of the species most frequently encountered.

Fish Production

Available records for the artificial ponds show that pond B produced more fish per unit area than any of the others. In 1934 this twenty acre pond produced 183,300 fingerling bass or 9,165 bass per acre. In 1935 the production dropped to 6,490 fingerlings per acre.

The highest production in pond A was 3,293 fingerlings per acre, which constituted the highest yield for a three year period.

Pond C has been eminently unsuccessful as a fish producer and except for the season of 1935 there are no records available. In that year the pond produced only 100 fingerling bass per acre, and even this low figure possibly represents the highest productivity attained by the pond.

In spite of the fact that all forms of fish life have been entirely eliminated from pond D (Hydes Lake) twice during the past eighteen years, its productiveness has been quickly restored by the introduction of pike fry, forage minnows, and adult suckers. Two years after its first "freeze out," thousands of pike averaging about 12 inches in length were being taken by hook and line fishing, and the lake had to be closed to fishing. A proper balance was restored in the third season, and thereafter fishing was normal, until the lake again "froze out" during the early part of 1936.

It is of interest that pond C which had the lowest phosphate and nitrogen concentrations, and which was least productive with respect to plankton, also produced the smallest number of fingerling bass. Another factor involved in the low productivity of the pond is the dissolved oxygen depletion which was observed to occur in summer as well as in winter. In its effect upon fish food, if not upon the fishes themselves, this depletion would have a marked influence upon the productivity of the pond and might conceivably constitute the limiting factor.

In pond A, dissolved oxygen reached a low level but complete depletion was not observed. It is possible, however, that reduction in oxygen may be responsible for a part of the difference in fish productivity which exists between this pond and pond B, for in other characteristics they are very similar. The low dissolved oxygen concentrations occurring in ponds A and C, especially during winter, may be attributed to oxygen depletion of the water supply. Pond A normally receives water diverted from a river. However, this water is often supplemented by well water which in winter, when the river is frozen, may become the sole supply. The well water is totally devoid of oxygen, but takes up a small quantity in passing over a two foot drop at the inlet. Pond C receives water from a creek which drains a large swamp. Decomposition of vegetation in this swamp reduces the dissolved oxygen and total depletion occurs at least during the winter season. Pond B is especially noteworthy for its constantly high dissolved oxygen concentration and a uniform water supply which is low in oxygen demand.

It is evident that the ponds described here compare favorably in physical, chemical, and biochemical characteristics with productive fish

waters elsewhere. With the exception of dissolved oxygen there was found no apparent lack of the elements essential to aquatic productiveness. Soluble phosphate was low, it is true, but it never disappeared completely, and it is probable that the deficiency was remedied by conversion of the organic to the soluble form. Soluble phosphate therefore, in spite of its reduction, cannot be considered a limiting factor in these ponds.

TABLE 1. RESULTS OF CHEMICAL ANALYSES OF THE WATER IN MINNESOTA FISH PONDS OCTOBER, 1933 TO AUGUST, 1934, INCLUSIVE RESULTS EXPRESSED AS P. P. M.

	POND A			POND B			POND C			POND D		
Determination Date:	11-1-33	2-8-34	8-9-34	11-2-33	2-9-34	8-10-34	10-31-33	2-7-34	8-7-34	11-3-33	2-14-34	8-9-34
Ammonia N	0.53	0.46	0.058	0.103	0.04	0.055	0.026	0.24	0.183	0.20	0.18	0.0057
Albuminoid N	0.72	1.4	1.0	0.214	0.13	0.4	0.249	0.24	0.444	0.99	0.64	1.2
Organic N	1.55	2.8	1.72	0.54	0.23	0.84	0.50	0.48	1.0	1.8	1.3	1.88
Nitrite N	Trace	Trace	0.0	0.02	Trace	0.0	Trace	Trace	0.0	Trace	0.0	Trace
Nitrate N	0.13	0.12	1.0	2.0	4.5	0.3	0.078	1.2	0.08	0.15	0.08	2.0
Total N	2.93	4.78	3.778	2.877	4.70	1.595	0.853	2.16	1.707	3.14	2.20	5.0857
Soluble PO_4	Trace	0.0919	0.0917	.0077	.0184	0.0765	Trace	0.0306	0.245	0.337	0.459	1.223
Organic PO_4	.398	0.3061	0.0000	.0689	.1046	0.0	0.138	0.1014	0.0614	0.521	0.0	0.0
Total PO_4	.398	0.3980	0.0917	.0766	.1230	0.0765	0.138	0.1320	0.3064	0.858	0.459	1.223
Insoluble sulphides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulphates (SO_4)	109.0	19.3	85.4	68.5	54.8	30.3	37.6	43.1	16.7	19.7	21.1	9.78
Potassium (K)	(.....	(.....	13.6	(.....	(.....	0.877	(.....	(.....	2.38	(.....	(.....	6.67
Sodium (Na)	(10.7	(41.6	24.7	(6.5	(8.86	1.033	(25.4	(9.29	4.15	(15.4	(18.3	5.98
Magnesium (Mg)	33.9	22	22.5	19.6	19.1	4.19	24.5	23.8	35	17.1	14.9	13
Calcium (Ca)	60.8	136	43.3	68.1	65.5	21.9	66.9	82.6	28.9	34.8	28.5	34.4
Aluminum (Al)	4.11	4.94	7.18	0.11	0.784	0.86	1.55	3.05	2.34	0.46	0.898	4.4
Silica (SiO_2)	20.8	28.5	20.9	15.7	18.8	26.7	12.5	26	17.4	36	28.2	29.8
Manganese (Mn)	0.13	0.35	Trace	Trace	Trace	0.0	Trace	0.25	0.10	Trace	0.10	Trace
Iron (Fe)	0.70	0.30	0.10	0.10	0.05	0.05	0.2	0.25	0.20	0.2	0.25	0.10
Chlorides (Cl)	3.5	8.0	2.0	7.0	8.0	5.5	4.0	3.0	0.5	7.0	5.0	5.0
Total Hardness (Soda Reagent)	390	416	226	250	270	123	320	311	194	165	139	163
Total Hardness (Calculated)*	290.9	430.5	230	250.66	242.5	79	268.5	304.4	212	157.3	132.7	170
Alkalinity (Phenol.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity (Total)	340	488	196	175	194	66	306	290	174	169	115	171
Total Solids	515.0	838	333	317.2	320	159	361.0	367	243	270.6	214	259
Total Volatile Matter	189.0	294	130	110.3	120	51.4	142.0	140	97	109	85	113
Suspended Solids (Gooch)	17.7	10.8	2.5	1.38	2.0	.....	0.333	3.25	0.7	5.88	12.7	3.43
Suspended Solids**	69.0	16.0	.....	0.2	3.0	.....	3.0	10	.....	2.6	10	.....
Dissolved Solids	446	822	330.5	317	317	.....	358.0	357	242.3	268	204	255.57
Dissolved Volatile Matter	174	285	.....	114	116	.....	145.0	135	.....	115	88	.....
Color	30+	.....	50	5	.....	20	15	.....	30	20	.....	25
Turbidity	23.0	20.0	6	1.5	2.5	2.0	1.2	3	2	4.0	4.0	7.0
Five-day B. O. D.	3.6	6.7	2.6	3.7	4.4	2.10	1.4	3.2	3.3	2.5	2.0	3.3
pH	8.0	7.9	.....	8.3	8.2	.....	8.3	7.7	7.9	8.1	7.7	.....
Dissolved Oxygen	8.3	1.4	6.2	10.4	21.2†††	8.2	16.3†††	3.5	0.0	9.6	4.5	7.9
Temperature	13°C.	2°C.	26°C.	10°C.	4°C.	26°C.	13°C.	2°C.	24°C.	6°C.	4°C.	26°C.

*Computed from the results of the determination of Ca and Mg.
**Obtained by subtracting dissolved solids from total solids.
†††Supersaturated.

TABLE 2. NUMBER OF PLANKTONTS PER LITER OF WATER IN THE CENTRIFUGE PLANKTON OF POND A*

Organism	Outlet 8-1-33 Serial No.: 43552	Outlet 11-1-33 44108	Outlet 2-8-34 44566	Inlet† 2-8-34 44567	Outlet 5-9-34 45692
ALGAE					
Myxophyceae, Blue-green Algae					
Anabaena	288	.....	.....	.....	2,592
Coelosphaerium naegelianum	864	7,767	.....	.....	1,728
Chroococcus	432	.....	.....	.....	.....
Gomphosphaeria lacustris	2,736	2,589	.....	.....	.....
Lyngbya	4,130	.....	.....	.....	.....
Merismopoedia sp.	432	.....	.....	.....	3,456
Merismopoedia tenuissima	9,504	.....	.....	.....	.....
Microcystis aeruginosa	720	3,452	.....	.....	.....
Microcystis flos-aquae	432	.....	.....	.....	.....
Oscillatoria sp.	.....	.....	.....	.....	Present
Oscillatoria tenuis	.....	5,178	.....	.....	.....
Phormidium sp.	.....	2,589	.....	.....	.....
	19,538	21,575	.....	.....	7,776
Bacillarieae, Diatoms					
Amphora ovalis	432	2,589	.....	.....	Present
Cocconeis placentula	2,478	4,315	.....	.....	29,748
Cyclotella	.....	4,264,740	.....	.....	.....
Cymbella	.....	.....	.....	.....	864
Fragilaria capucina	.....	.....	.....	Present	2,592
Fragilaria mutabilis	.....	.....	.....	.....	Present
Gomphonema acuminatum	432	.....	.....	.....	1,296
Lysigonium	.....	.....	.....	Present	.....
Navicula	2,016	6,041	.....	1,725	24,790
Pinnularia	6,608	1,726	.....	.....	.....
Sphinctocystis elliptica	.....	.....	.....	.....	Present
Synedra tenuissima	4,130	.....	.....	Present	12,395
Synedra ulna	Present	.....	.....	.....	9,916
	16,096	4,279,411	.....	1,725	81,601
Chlorophyceae, Green Algae					
Actinastrum hantzschii	.....	.....	.....	.....	Present
Ankistrodesmus falcatus	.....	379,720	2,094,532	.....	.....
Closterium acutum	.....	95,793	.....	.....	.....
Closterium sp.	.....	.....	.....	.....	864
Cosmarium	288	.....	.....	.....	3,024
Crucigenia rectangularis	1,152	Present	.....	.....	1,296
Dictyosphaerium ehrenbergianum	.....	.....	.....	.....	864
Dictyosphaerium pulchellum	.....	.....	.....	.....	Present
Elakatothrix	576	.....	.....	.....	.....
Gleocystis	.....	.....	.....	.....	2,160
Oocystis	12,390	Present	.....	.....	.....
Pediastrum boryanum	.....	.....	.....	.....	2,592
Scenedesmus bijuga	.....	.....	.....	.....	4,752
Scenedesmus quadricauda	Present	.....	.....	.....	5,184
Sphaerocystis schroteri	.....	1,726	.....	.....	1,296
Staurastrum	288	.....	.....	.....	864
	14,694	477,239	2,094,532	.....	22,896
PROTOZOA					
Mastigophora					
Chlamydomonas	.....	85,437	312,444	1,150	257,816
Cryptoglena pigra	.....	3,452	.....	.....	.....
Euglena	.....	9,493	.....	Present	864
Gymnodinium	.....	.....	.....	.....	8,460
Pandorina	288	.....	.....	.....	.....
Phacus	.....	.....	.....	1,725	.....
Phacus pleuronectes	Present	.....	.....	.....	.....
Trachelomonas volvocina	9,912	818,235	399,234	.....	Present
Volvocales sp.‡	.....	.....	8,158,260	.....	.....
	10,200	916,617	8,869,938	2,875	267,140
Infusoria					
Ciliate protozoa	1,152	18,123	2,513	12,650	1,728
Codonella cratera	.....	15,534	.....	1,725	.....
Vorticella	Present	.....	.....	2,875	.....
	1,152	33,657	2,513	17,250	1,728
IRON BACTERIA					
Leptothrix ochracea	.....	.....	.....	168,606	.....
TOTAL	61,680	5,728,499	10,966,983	190,456	381,141

*Almost the entire volume of water used comes from a well during the coldest part of the winter season.

†Sample taken from inflow pipe.

‡Probably Chlamydomonas.

**Obtained from subtracting the determination of Ca and Mg. ††Supersaturated.

***Obtained by subtracting dissolved solids from total solids.

TABLE 3. NUMBER OF PLANKTONTS PER LITER OF WATER IN THE CENTRIFUGE PLANKTON OF POND B

Organism	Date: 11-2-33 Serial No.: 44126	2-9-34 44569	3-10-34 45696 A
ALGAE			
Myxophyceae, Blue-green Algae			
Anabaena	.....	.....	Present
Chroococcus	.....	.....	720
Lyngbya	.....	.....	20,660
Microcystis	576	.....	.....
Merismopoedia	Present	.....	.....
Oscillatoria	.....	Present	.....
	576	.....	21,380
Bacillariceae, Diatoms			
Amphora ovalis	33,060	14,868	.....
Cocconeis placentula	13,224	.....	5,400
Cyclotella	353,742	120,596	.....
Cymbella	.....	432	1,080
Fragilaria capucina	Present	Present	1,080
Gomphonema	24,795	826	28,924
Lysigonium	2,304	.....	.....
Navicula	208,278	128,030	82,640
Stauroneis	150	432	.....
Synedra tenuissima	190,095	34,692	.....
Synedra ulna	320	7,434	1,800
	825,968	307,310	120,924
Chlorophyceae, Green Algae			
Ankistrodesmus falcatus	79,344	288	.....
Cosmarium	.....	.....	2,160
Scenedesmus bijuga	.....	Present	.....
Scenedesmus dimorphus	1,152	.....	.....
Scenedesmus quadricauda	11,571	Present	720
Staurastrem	Present	.....	.....
	92,067	288	2,880
PROTOZOA			
Mastigophora			
Chlamydomonas	.....	21,476	433,860
Euglena	576	.....	720
Glenodinium	.....	1,008*	.....
Palmelloid colonies	.....	288	.....
Trachelomonas volvocina	1,440	9,912	181,808
	2,016	32,684	616,388
Infusoria			
Ciliate protozoa	2,016	2,016	2,160
	2,016	2,016	2,160
TOTAL	922,643	342,298	763,732

*Aciculiferum.

TABLE 4. NUMBER OF PLANKTONTS PER LITER OF WATER IN THE CENTRIFUGE PLANKTON OF POND C

Organism	Date: 10-31-33 Serial No.: 44104	2-7-34 44559	8-7-34 45690
ALGAE			
Myxophyceae, Blue-green Algae			
Anabaena	.....	.....	Present
Lyngbya	.....	120,654	.....
Oscillatoria	6,608	.....	1,440
	6,608	120,564	1,440
Bacillarieae, Diatoms			
Amphora ovalis	432	Present	1,440
Cocconeis placentula	14,042	Present	30,990
Cyclotella	52,864	.....	.....
Cymbella	.....	.....	Present
Cystopleura sorex	288	.....	.....
Fragilaria	Present	Present	12,396
Gomphonema acuminatum	7,434	1,440	30,990
Gomphonema constrictum	.....	.....	Present
Gompronema sphaerophorum	.....	Present	Present
Homoeocladia acicularis	.....	.....	Present
Homoeocladia amphibia	.....	.....	111,564
Navicula	18,172	1,728	59,914
Pinnularia	.....	.....	1,440
Rhoicosphenia curvata	.....	288	Present
Synedra tenuissima	3,312	19,824	12,396
Synedra ulna	4,956	288	24,792
	101,500	23,568	285,922
Chlorophyceae, Green Algae			
Ankistrodesmus falcatus	576	Present	.....
Cosmarium	.....	.....	720
Gloeocystis	Present	.....	.....
Scenedesmus dimorphus	Present	.....	.....
Scenedesmus quadricauda	576	Present	10,330
	1,152	.....	11,050
PROTOZOA			
Mastigophora			
Chlamydomonas	.....	1,584	126,026
Euglena	.....	7,434	720
Glenodinium	.....	.....	1,800
Trachelomonas volvocina	3,304	.....	68,178
	3,304	9,018	196,724
Infusoria			
Ciliate protozoa	432	7,488	10,440*
TOTAL	112,996	160,638	505,576

*Chiefly Halteria sp.

TABLE 5. NUMBER OF PLANKTONTS PER LITER OF WATER IN THE CENTRIFUGE PLANKTON OF POND D

Organism	Date: 11-3-33 Serial No.: 44146	2-14-34 44474	3-9-34 45694
ALGAE			
Myxophyceae, Blue-green Algae			
Anabaena	.....	.....	422,210
Aphanizomenon	19,840	.....	.....
Coelosphaerium naegelianum	.....	.....	1,296
Lyngbya	.....	.....	867,650
Microcystis aeruginosa	648	.....	.....
Oscillatoria	.....	.....	64,454
	20,488	.....	1,355,610
Bacillarieae, Diatoms			
Amphora ovalis	864	Present	.....
Cocconeis placentula	29,760	576	37,185
Cyclotella	39,680	Present	.....
Cystopleura sorex	432	.....	.....
Diatoma vulgare	Present	.....	.....
Fragilaria	.....	.....	Present
Fragilaria capucina	2,160	.....	.....
Gomphonema acuminatum	2,376	Present	864
Homoeociadia	.....	.....	Present
Lysigonium	1,080	.....	.....
Navicula	9,920	Present	22,311
Sphinctocystis librilis	Present	.....	.....
Synedra tenuissima	Present	.....	4,958
Synedra ulna	6,200	720	27,269
	92,472	1,296	92,587
Chlorophyceae, Green Algae			
Actinastrum	.....	.....	Present
Ankistrodesmus falcatus	432	266,798	.....
Coelastrum microporum	.....	.....	Present
Cosmarium	.....	.....	29,749
Crucigenia rectangularis	.....	.....	1,728
Dictyosphaerium pulchellum	.....	.....	2,160
Oocystis	.....	.....	74,370
Scenedesmus arcuatus	.....	.....	Present
Scenedesmus bijuga	.....	.....	Present
Sphaerocystis schroteri	.....	.....	12,096
	432	266,798	120,102
PROTOZOA			
Mastigophora			
Chlamydomonas	.....	.....	3,024
Trachelomonas volvocina	Present	288	1,728
Volvocales (unidentified)	.....	288	.....
	.....	576	4,752
Infusoria			
Ciliate protozoa	.....	864	11,664
TOTAL	113,392	269,534	1,584,715

TABLE 6. NUMBER OF ORGANISMS PER 100 LITERS OF WATER IN THE NET PLANKTON, NOVEMBER, 1933

Organism	Pond A Inlet	Pond A Outlet	Pond B	Pond D
Date:	11-1-33	11-1-33	11-2-33	11-3-33
Serial No.:	44106	44109	44127	44145
PROTOZOA				
Sarcodina				
Arcella	.....	.....	Present	.....
Infusoria				
Codonella cratera	1,920	82,450	.....	.....
Vorticella	.....	.....	Present	.....
	1,920	82,450	.....	.....
ROTIFERA				
Brachionus calyciflorus	.....	150	100	.....
Diurella sp.	.....	.....	Present	.....
Filinia longiseta	.....	.....	50	.....
Keratella cochlearis	2,800	1,100	100	50
Lecane sp.	.....	.....	.....	50
Synchaeta	.....	.....	250	.....
Other Rotifers	50	50	200	.....
	2,850	1,300	700	100
CLADOCERA				
Bosmina obtusirostris	300	1,850	.....	.....
Ceriodaphnia quadrangula	.....	.....	.....	50
Chydorus sphaericus	.....	.....	.....	350
Daphnia pulex	50	.....	Present	1,000
	350	1,850	.....	1,400
COPEPODA				
Cyclops bicuspidatus	700	50,200	300	600
Cyclops serrulatus	1,050	.....	.....	.....
Diaptomus clavipes	200	350	50	.....
Diaptomus pallidus	.....	.....	.....	1,050
Diaptomus sicilioides	50	600	.....	.....
Nauplii	400	1,500	4,650	50
	2,400	52,650	5,000	1,700
TOTAL	7,520	138,250	5,700	3,200

TABLE 7. NUMBER OF ORGANISMS PER 100 LITERS OF WATER IN THE NET PLANKTON, FEBRUARY AND AUGUST, 1934

Organism	Pond A* Date: 2-5-34 Serial No.: 44565	Pond C 2-7-34 44560	Pond D 2-14-34 44575	Pond A* 8-9-34 47313	Pond B 8-10-34 47315	Pond C 8-7-34 45691	Pond D 8-9-34 47314
ALGAE							
Myxophyceae, Blue-green Algae							
Microcystis	.....	.....	250	.....	2,816	.....	160,512
			250	.....	2,816	.....	160,512
PROTOZOA							
Sarcodina							
Arcella	.....	.....	.....	300	Present	3,000	.....
Centropyxis aculeata	.....	.....	.....	.....	Present	Present	.....
Difflugia	.....	.....	.....	.....	.....	300	.....
			.....	300	.....	3,300	.....
Mastigophora							
Ceratium	.....	.....	.....	.....	Present	.....	.....
Pandorina	.....	.....	.....	.....	Present	.....	.....
Pleodorina	.....	.....	.....	.....	3,520	.....	1,408
Volvox	.....	.....	.....	.....	100	.....	.....
			.....	.....	3,620	.....	1,408
ROTIFERA							
Asplanchna	.....	.....	.....	.....	.....	.....	200
Brachionus sp. No. 1	.....	.....	.....	100	.....	.....	.....
Brachionus calyciflorus	2,700	.....	.....	.....	.....	.....	.....
Brachionus havanaensis	.....	.....	.....	.....	Present	.....	.....
Brachionus patulus	.....	.....	.....	3,100	9,152	100	2,000
Euchlanis dilatata	.....	.....	.....	.....	.....	Present	3,600
Keratella aculeata	Present	.....	.....	.....	Present	.....	.....
Keratella cochlearis	.....	.....	.....	33,088	.....	.....	12,100
Lecane	.....	.....	.....	704	.....	.....	600
Lepadella	.....	.....	.....	1,056	Present	800	300
Monostyla	.....	.....	.....	1,056	Present	300	600
Monostyla quadridentata	.....	.....	.....	.....	Present	150	.....
Notholca striata	450	50	.....	.....	.....	.....	.....
Pedalia mira	.....	.....	.....	.....	Present	.....	.....
Polyarthra trigla	.....	.....	.....	20,064	1,408	Present	300
Soft-bodied Rotifers	11,400	.....	.....	Present	.....	.....	200
Synchaeta	75	.....	.....	.....	14,784	.....	400
Testudinella patina	.....	.....	.....	150	.....	.....	Present
Trichocera cristata†	.....	.....	.....	.....	.....	.....	600
Trichocera rattus	.....	.....	.....	50	.....	.....	.....
Trichotria tetractis	.....	.....	.....	704	.....	Present	150
	14,625	50	.....	60,072	25,344	1,350	21,050

CLADOCERA							
Alona	.....	.....	.....	.....	.....	50	.....
Bosmina obtusirastris	225	.....	.....	.....	25,344	.....	.....
Camptocerus rectirostris	.....	.....	.....	.....	.....	50	.....
Ceriodaphnia reticulata	.....	.....	.....	.....	Present	.....	.....
Chydorus sphaericus	.....	.....	.....	.....	.....	.....	400
Daphnia	.....	.....	.....	.....	.....	50	.....
Daphnia longispina	300	.....	.....	.....	.....	.....	.....
	525	.....	.....	.....	25,344	150	400
COPEPODA							
Cyclops‡	5,925	.....	.....	500	11,264	350	.....
Diaptomus	.....	.....	150	.....	.....	.....	500
Diaptomus sicilis	1,200	.....	.....	.....	.....	.....	.....
Nauplii	9,000	.....	200	26,048	61,952	6,900	3,800
	16,125	.....	350	26,548	73,216	7,250	4,300
OSTRACODA	.....	.....	.....	.....	.....	400	.....
			.....	.....	.....	400	.....
TOTAL	31,275	50	600	86,920	130,340	12,450	187,670

* Outlet
† Also called Rattulus carinatus.
‡ Chiefly bicuspidatus, although a few adult Cyclops serrulatus occurred in Sample No. 47315.

TABLE 8. PRODUCTIVITY OF ARTIFICIAL FISH PONDS IN 1934, 1935

Pond	Brood Stock per Acre	Fingerlings per acre	Year
A	11.6	913	1934
A	11.0	3,293	1935
B	15.7	9,165	1934
B	17.0	6,490	1935
C	30.0	100	1935

TABLE 9. DESCRIPTION AND PRODUCTIVITY OF PONDS A, B, C, AND D

Pond	Type	Source of Water Supply	AVERAGE			Area Acres	Bottom Type	1934		1935	
			Length in ft.	Width in ft.	Depth in ft.			Brood Stock	Fingerlings Produced	Brood Stock	Fingerlings Produced
A	Excavated—artificial	River and Well	1,460	300	3½	8½	Clay and muskeg	99	7,750	94	28,000
B	Flooded meadow—artificial	Spring fed creek	2,100	500	3	20	Clay and muskeg	220	183,300	240	129,800
C	Flooded creek bed—artificial	Creek from swamp area	1,400	435+	3	14	Clay, silt and gravel	....	.....	420	3,000
D	Small lake—natural	Springs and natural drainage. No effective inlet or outlet	3,600	2,100	10	176	Sand and muck	See descriptive paragraph on page 23			

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MICHIGAN LAKE SURVEY—A COOPERATIVE ENTERPRISE

DONALD E. MILLER

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Mich.

The major modifications in the methods used in lake inventory in Michigan during the past year are related to the assistance and cooperation given the Institute for Fisheries Research by a number of other agencies in the state. It is the primary purpose of this paper to point out these changes during the past year.

The M.E.C.W. has made the geographical survey of a number of lakes. The Parks E.C.W., the Resettlement Administration and the U. S. Forest Service have assisted, to some extent, in mapping certain other lakes. This part of the survey involves the making of a shore line map either by direct survey or by enlargement, on cross section paper, of an aerial map. By means of proper symbols various shore features such as positions of cottages, inlets, outlets, high ground, encroaching shore, etc. are added. After this has been completed the lakes are sounded at intervals of 100-400 feet along lines designated at the time of the marginal survey. At strategic points such as in the region of the drop-off the distance between soundings is reduced to intervals as small as 25 feet. A bench mark or less complicated position must be established at the time the soundings are made so that the difference in lake level at any future time can be determined. Since drifted snow may hide many shore line features, it is best to make the marginal survey when there is no snow. Soundings are easily and accurately made through holes chopped or bored in the ice along lines designated at the time of the shore line survey.

Some difficulties have arisen in instances where enlargements were made from aerial maps. Usually it is necessary to use aerial maps which have been made several years before. During the intervening period the lake level may have changed considerably, making large bays into dry land or swamp, exposing much gravel, etc. Also, shore features such as cottages are not shown well on such a map.

The map showing shore line features and soundings is prepared in the field office of the group handling the survey. This it sent to the E.C.W. drafting office where it is transferred to tracing paper, contours being added instead of soundings. Blue-line prints are then made for the Institute.

The geographical survey is only a preliminary step in the lake inventory. However, since it is time consuming, especially on larger

lakes, the amount of work which can be done by the biologists is greatly increased. On large lakes the geographical survey takes more time than all other operations put together.

The blue-line maps with bottom contours are taken into the field when the chemical physical and biological surveys are made. Data in regard to the location, kind and abundance of vegetation, location of spawning beds, gravel areas and kind of bottom are added to the maps by means of appropriate symbols. These data are later transferred to the original tracing cloth map by the M.E.C.W. draftsmen. Blue-line prints are again made and the kind of bottom added in colors.

Men from the various groups have helped, under the direct supervision of the biologists, with the manual labor connected with the biological survey, such as rowing boats, assisting with seining and gill netting of fish, collecting and screening of bottom samples, etc. Since only three to ten days are spent in securing the biological and chemical-physical data of any one lake, new men have to be introduced to this work frequently, but whenever possible the experienced men can be used to greater advantage.

The Institute survey crews consist of three men each. Two of these are trained biologists and the other is supplied by the hatchery which distributes fish to the district. The hatchery man knows the locality, the present status and history of fishing in particular lakes, the desires of fishermen in the district, and is able to contribute other information. In addition, he assists in most of the operations of the party and becomes acquainted with survey methods.

Methods for the securing of most biological and physical-chemical data in the Michigan Lake Inventory have been described by McMurry, Eschmeyer, and Davis (1933). However, certain additional data were secured during the past summer, and a brief description of the methods used are included here.

Measured, vertical or horizontal plankton hauls were made by means of a closing plankton net. In the field, the volume of plankton which precipitated after twenty-four hours of preservation was measured. The volume of plankton per cubic meter was then calculated. Hauls were made at several stations on each lake if it seemed important to do so. All samples were preserved for future study.

Bottom samples were secured from various depths by means of an Ekman dredge, two samples being taken at each depth. The bottom material was passed through a number twenty brass screen. The organisms left on the screen were preserved and their approximate volume was determined, when possible, in the field. All samples were preserved for further study.

A plant collection accompanied by a label giving the place where taken, the type of bottom and the depth of water in which it was growing, was made from each lake surveyed.

Up to 1936 about 150 lakes were surveyed. During the past summer about twenty-five more, including some of the largest lakes in Michigan, were added to the list. It is hoped that with the continued cooperation of the various agencies considerable progress may be made in the future.

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THE GREAT LAKES FISHERIES: THEIR PROPER MANAGEMENT FOR SUSTAINED YIELDS

JOHN VAN OOSTEN

In Charge, Great Lakes Fishery Investigations, U. S. Bureau of Fisheries, Ann Arbor, Mich.

The Great Lakes and their connecting waters form the largest single fresh water area in the world. They have a combined surface of more than 95,000 square miles (60,909,000 acres) which comprises nearly 1/3 of all the fresh water area in the United States and Canada. Their combined shore lines total more than 8,300 miles and their combined lengths aggregate more than 1,600 miles, the equivalent of the greatest length north and south of the continental United States. The United States owns some 64 per cent of the area of these lakes, which is about 54 per cent of all the fresh water surface area found in our country. All of the Great Lakes, except Erie and St. Clair, have a depth of more than 700 feet, the greatest known depth, 1,290 feet, being found in Lake Superior.

The importance of these inland waters to our nation lies not only in the facts that they form a natural transportation highway for commerce, that they afford access to a region of our country notable for the grandeur of its natural scenery, that they are the center of a rich historic lore, and that they provide a playground for the nation, but also in the fact that they are the nation's primary source of supply of fresh-water fish.

IMPORTANCE OF THE FISHERIES TO THE NATION

The significance of the commercial fishery industry on the Great Lakes to the life of our nation is not clearly understood by the general public. For example, the public does not realize that of the more than 144 million pounds of fresh-water fish *produced* in the United States annually, with a value to the fishermen of nearly $9,000,000, more than 90 million pounds, with a value of nearly $6,000,000, or some 63 per cent, comes from the United States waters of the Great Lakes, or that of the 187½ million pounds of fresh-water fish *consumed* in the United States annually some 48 per cent, or nearly one half, is supplied by the United States fishermen of these lakes. Further, the Great Lakes are the only commercial sources of such species as the lake trout, yellow perch, chubs, Lake Erie cisco, lake herring, suckers, blue pike and sauger. They are also the principal United States sources of the widely advertised whitefish and of the yellow pike-perch. The importance of the Great Lakes to the nation with respect to the fisheries lies, then, in the fact that these lakes produce nearly all of the most highly prized class of fresh-water fish purchased by our people.

Commercial Extermination of Some Species a Fact

It is because of this economic position of the Great Lakes fisheries in the life of the nation that the United States Government, through the facilities of the U. S. Bureau of Fisheries, has from time to time made an earnest effort to study these fisheries in order to determine whether they are being depleted and if so what factors are involved and what remedies are required.

We have learned already that disaster has overtaken some of the more valuable species that formerly teemed in the Great Lakes waters. The lake sturgeon, once considered a nuisance in the fishermen's nets, due to its abundance, and recklessly piled like cord wood on shore and burned, has now become a museum curiosity. The bluefin in Lake Superior, the blackfin in Lake Michigan, and the bloater in Lake Ontario are now commercially extinct. The other species of chubs have likewise been so seriously reduced in numbers in all of the Great Lakes that the many fishermen who depend on them for their living find themselves in straightened circumstances. The once abundant yellow pike-perch of southern Green Bay has disappeared and the yellow perch of this bay are in danger of suffering the same fate. The whitefish formerly distributed in great abundance everywhere along the shores of the Great Lakes now supports the fishery only in certain restricted areas, and during the last five years many of these have been seriously depleted. Recently the once valuable Lake Erie cisco fishery has been completely wiped out commercially, the United States production of ciscos having dropped from about 21¼ million pounds in 1924 to 111,000 pounds in 1934, a decline of 99.5 per cent in ten years. Because of the commercial extermination of the cisco the present supply of blue pike and yellow perch in Lake Erie is threatened, since these species are now the only ones left that can be taken in profitable quantities in certain types of gear.

The situation on the Great Lakes is more serious than the public surmises. In fact, the history of the Great Lakes fisheries parallels closely the well known history of the forests, the game fish, the game animals, and the game birds and water fowl of the same region. The waste and burnt-over lands of the Great Lakes states find their counterparts in the large areas of lake bottoms that once teemed with whitefish, lake trout, and other species, but now produce none of these fish. Unless some firm action is taken, and taken soon, the productivity of the lakes that are still supporting a fairly large fishing industry will repeat the history of production on Lake Ontario where the former average annual yield of some 3 million pounds of fish has dwindled for many years to around 500,000 pounds and where at the present time only small fishing rigs can afford to operate due to the extreme scarcity of fish.

Control of the Fisheries and Discretionary Power

The question arises, "What must be done to avert continued devastation of these fisheries?" Much information has been accumulated since the first survey of the Great Lakes fisheries was inaugurated in 1871 by the U. S. Commission of Fish and Fisheries, but only a small part of the recommended legislation based on this information has been adopted by the legislatures of the various states involved. Contrary to the belief of many people the Great Lakes fisheries are not under the jurisdiction of the federal government but are administered by the eight states fronting the Great Lakes, namely, New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin, and Minnesota, and by the Province of Ontario. The federal government may investigate, advise, and recommend, but the states must enact and enforce their respective fishery laws.

Here we encounter our first major problem in the management of the Great Lakes fisheries. Every fisheries survey, every fisheries investigator, virtually every fisheries administrator, and commercial fisherman on the Great Lakes have stressed the point at one time or another that the fisheries of each lake must be governed by uniform regulations, uniform methods of enforcement, and uniform enforcement. That such uniformity is essential is apparent from the simple fact that virtually every commercially important species of fish migrates back and forth in the waters of a lake without reference to any state or international boundaries. Fishermen of adjoining states fish side by side and derive a living from the same population of fish. On Lakes Erie and Huron American and Canadian fishermen operate within sight of one another. Uniform regulation is further necessary to avoid discrimination and unfair competition among the Great Lakes fishermen. For example, in the fall of 1935 Michigan was required by law to enforce a closed season on the chubs of Lake Huron, thus compelling the Michigan chub fishermen to discontinue their operations for a period of six weeks; but the Canadian fishermen continued their operations on this lake to take the fish protected by Michigan laws. Such discriminating variations in the laws of the different states or of the two countries occur also with respect to size limits, size of net mesh, and other regulations. It is obvious then that unless all parties who have joint jurisdiction of such international or interstate populations of fish agree on proper regulations these populations of fish can not survive. Further, it is unfair to ask one state or country to conserve a particular fishery while the neighboring state or country is recklessly exploiting that same fishery. It is largely because of this discrimination that adequate and constructive legislation can not be passed in the various legislatures at the time when such legislation is urgently needed to save a fishery.

The question may now be asked, "What can be done to remedy this situation?" Many attempts have been made by federal, state, and provincial officials to reach uniform agreements in the regulation of the

Great Lakes fisheries. Records show that interstate and international conferences were held on the Great Lakes in 1883, 1884, 1891 (two), 1892, 1897, 1904, 1905 (two), 1927 (two), 1928 (two), 1929, 1931, 1932 (two), 1933, 1934 and 1936 (three). At least 22 conferences have been held, thirteen during the last ten years, at which agreements on uniform regulations were reached by the officials of the various conservation departments concerned, but for various reasons concurrent adoption or enforcement has up to the present time been impossible. We know what measures are needed to advance the rehabilitation of the fisheries, but under the present system of control we are absolutely helpless in having these measures enacted into the several codes. Knowing the nature of the complications and difficulties involved and actually experiencing repeated failures in the many attempts during the past ten years to obtain some coordinated action among the several states, I am forced to the opinion that uniformity will never be established on the Great Lakes as long as the control of the fisheries is divided among the nine enforcement agencies. With divided control the Great Lakes fisheries can never be managed properly. Only an international or at least an interstate agency with full powers to regulate the industry without any political interference whatsoever can avert further disaster to these fisheries.

I regret that I must finally come to this conclusion for I have always been an enthusiastic proponent of coordinated regulation of the fisheries of each of the Great Lakes. In fact, "coordinated regulation by the states" was the chief objective of virtually all of the U. S. Bureau of Fisheries major field investigations on the Great Lakes during the past ten years. The point has now been reached, however, where the question of state versus federal rights should be placed in the background as it has been done to a large extent in the regulation of our forests and migratory birds, and where the states and federal government should join forces, for as in the case of the forests and migratory birds we are faced with the problem of averting the commercial extermination of a valuable natural resource of not only local but of national and international importance. I care not what kind of a central agency is established just so we have central control dominated by men who are gifted with the faculty of promoting real conservation measures with an eye not only to present conditions but to the future as well.

Effective fisheries management requires a fisheries manager with the means and the power to act. I can not stress this point too strongly. This, of course, implies that provision must be made for a certain amount of discretionary power in regulating the Great Lakes fisheries. This power should be so circumscribed as to safeguard the industry from any violent upsets or radical measures. In promoting regulations consideration must always be given to the question, "What will be the immediate effect on the industry?" After all, our goal is not alone simply to conserve for posterity the several species of fish found in

the Great Lakes but to protect a nationally important source of food supply for the present generation and to perpetuate and establish on a firm basis the present fishing industry, a nationally important source of income. We want maximum production and sustained yield, an abundant food supply and a prosperous industry. We want to satisfy the man of today as well as the man of tomorrow. These objectives can be reached only by intelligent management. As evidence for this I need to point only to the excellent work of the U. S. Bureau of Fisheries in gradually building up the population of seals in the Pacific Ocean and in rehabilitating the salmon fisheries of Alaska, and to the fine results obtained by the International Halibut Commission in ending the continuing decline of the valuable halibut in the Pacific Ocean.

Fisheries Statistics and Statistical Standards

In order to manage the Great Lakes fisheries properly we must provide further for more accurate and more complete statistics on the catch and on fishing operations. These statistics must be collected and compiled in accordance with a uniform system and uniform standards. Until the more refined methods of statistical analysis are adopted by all states and the Province of Ontario it will be impossible to follow the real trend of every fishery, predict fluctuations in future yields, or check the effectiveness of any new restrictive regulations that may be imposed on the fisheries of a lake. Much credit is due the State of Michigan for its pioneering leadership in inaugurating and actually enforcing since 1927 a system of collecting statistics which has enabled the Bureau's staff at Ann Arbor to undertake the problem of developing proper standards.

The problem of devising reliable statistical standards for the Great Lakes fisheries has been found to be extremely complicated—much more complex than any one of us working with it ever suspected. Perfectly reasonable and logical deductions were more than once found to be invalid, and in certain cases results obtained appeared to be absolutely inexplicable. It has been found already that the statistical standards employed by fisheries biologists in other sections of the country can not be applied to the fisheries of the Great Lakes. For example, the universally accepted standard usually defined as, "the catch per unit gear per unit fishing time," if applied to the Great Lakes fisheries would give an entirely erroneous picture of actual conditions of abundance. From the evidence at hand abundance will probably have to be described in terms of "the average net lift, corrected for fishing time," rather than in the theoretically correct terms of "the average catch per net per night," as has been done so far. It is not known at present where the studies of Michigan's statistics will lead, but it is certain that reliable standards can be worked out, and when this is done these should be adopted by every Great Lakes state and the Province of Ontario and rigidly adhered to.

Causes of Fluctuations in Production

Intimately linked with the study of trends in abundance is the question of the various causes or factors of abundance. Of paramount importance in this connection is the question of abundance of year classes. Except in cases where the species has reached the point of commercial insignificance no one can positively determine the real trend of a fishery without a knowledge of the age composition of the catch and rate of growth of the species. The collection of statistics should, therefore, proceed hand in hand with the collection of biological data on length, weight, sex, sexual maturity, and of samples of scales for age and growth determination.

There are, of course, other factors of abundance that must also be taken into consideration in analyzing trends. In brief, the causes of fluctuations in the fish yield of the Great Lakes may fairly well be classified under four groups: (1) economic; (2) technological; (3) environmental; and (4) biological. Under the economic we may list such items as market conditions, price, labor disputes, economic depression, war, etc. Technological factors include such items as quantity of gear employed, modification in the construction of the dominant type of gear, introduction of new and more efficient types of gear and machinery, changes in method of fishing, improvement of shipping, storage, and freezing facilities, intensified or relaxed enforcement of regulations, adoption of new regulations, increased efficiency or production of hatcheries and the availability of suitable bait. The environmental factors include weather conditions, such as wind, currents, temperature, turbidity of the water and pollution. The biological factors involve, in addition to those already mentioned (age, growth, sexual maturity, and abundance of year classes), conditions with respect to food, predators, parasites, disease, spawning, mortality, migration, vertical and horizontal distribution, habits, density of populations and the like.

Although all of these various types of factors must be considered in studying trends, I do not believe that it is wise always to withhold regulatory action until the final analysis of every factor has been completed. I believe in "safety first" and, therefore, contend that notwithstanding all theoretical arguments to the contrary if the total annual production continues to decline each year regulatory measures are justified. After all, biological and environmental factors can not be controlled by man, and it is at least safe to assume that under the circumstances curtailment of the catch will never harm the supply in the lakes.

Races of Fish and Migration

Some of the problems just listed in relation to statistical analysis have perhaps greater significance from the point of view of fishery management than others. Thus the questions of the existence of local populations or races and migration are of paramount importance in any management program. To manage the Great Lakes fisheries intelligently

and to interpret correctly statistics on abundance for each geographical unit, it is essential to know whether there is one homogeneous population of lake trout, chub, whitefish, or other species in the lake, or whether there are a group of wholly independent units forming schools or races. If separate groups exist, it must be determined whether these remain confined to local areas or whether they tend to migrate either continually, periodically, or seasonally as a group from one region of the lake to another. It must be ascertained whether the spawning populations on the various grounds and the schools of different regions in the lake are self-maintaining or whether their size fluctuates from year to year due to the haphazard or erratic influx of fish from other grounds or regions. If the various schools of a lake act as independent populations and occupy permanently a definite area of a lake, fisheries management becomes a problem of controlling a series of independent populations instead of only one large population. Local regions rather than the entire lake become the units of administration, and management becomes much more complicated. The solution of this problem requires, among other things, extensive tagging of the more important commercial species of fish. Successful tagging will also give us incidentally direct information on the problem of intensity of fishing, that is, rate of mortality and on rate of growth.

Experimental Study of Fishing Gear

Another major problem in the management of the Great Lakes fisheries is the experimental study of the action of the various types of commercial fishing gear on the various species of fish and the reaction of these fish to the various types of gear. Commercial fishing is probably the only factor involved in the abundance of fish that can be placed under the immediate control of man. The Great Lakes are too large to be subjected to environmental control or lake improvement. The effectiveness of artificial propagation on the Great Lakes is still a subject for debate. Since depletion is largely a question of a proper balance between mortality and replacement, or, if you please, between outgo and income, and the income on the Great Lakes can not as yet be controlled by man while the outgo can be curtailed only by the regulation of fishing operations or gear, it is very important that much more data be collected on the selectivity of fishing gear, so that it can be controlled intelligently and without undue hardship to the fishermen. Our recent experiments with various types of nets have shown conclusively that by the introduction of certain modifications in the construction of nets much can be done to reduce the wastage and destruction of immature fish and that thereby more can probably be done at virtually no cost, toward the replacement of marketable fish than could be done by a score of hatcheries at considerable cost .

Artificial versus Natural Propagation

Proper management requires further the scientific evaluation of the relative merits of artificial and natural propagation with respect to the

lake trout, the whitefish, and the pike-perches. The solution of this complicated and controversial problem on the Great Lakes would definitely fix the policy with reference to closed seasons during spawning periods and to the spawning permit system. If artificial propagation were found to be a more effective and economically sound method for producing fish than natural propagation, we would have it in our power not only to regulate the outgo, or the rate of mortality, but also to increase materially the income, or the rate of replacement, of the Great Lakes fish. In that event the greater the rate of replacement, that is, the greater the output of the hatcheries, the less would be the need for curtailment of the annual production of fish.

Introduction of Exotic Forms

The last item that I wish to mention briefly is the introduction of exotic forms. Such introduction can upset and complicate the best planned management program. We are at present undergoing a bitter experience with the introduced smelt in the Great Lakes and the time has arrived when some definite decision must be made concerning this species. Shall we attempt to exterminate it and bring forth curses on our heads from the sporting populace, or shall we protect the species, permit the introduction of small meshed gill nets to take the adults and threaten the existence of the larger and more valuable native species by wiping out their young? I believe it would be a good policy never to introduce into the Great Lakes an exotic form but rather to cultivate the highly prized native species of which there is no dearth of variety.

To recapitulate briefly, I believe that the proper management of the Great Lakes fisheries for sustained yields must include consideration of the following:

1. Centralized control and discretionary power.
2. Reliable fisheries statistics and statistical standards.
3. Investigation of the causes of fluctuations in yield with special emphasis on abundance of year classes.
4. Studies of populations or races and their movements or migrations.
5. Experimental studies of fishing gear and the behavior of fish toward the various types.
6. Evaluation of artificial and natural propagation.
7. Control of exotic species of fish.

If our program is to succeed, however, we must have the confidence, active support, and closest cooperation of the majority of the commercial fishermen, and there must be a frank and friendly exchange of counsel, advice, and information between these fishermen and the management. The fishermen should become more familiar with the ideas underlying fisheries management and should develop the same view point toward their product of commerce as the farmer has developed toward his crops. With such a viewpoint the Great Lakes fisheries would be husbanded and harvested—not exploited.

THE BIOLOGICAL AND ECONOMIC IMPORTANCE OF THE SMELT IN GREEN BAY

EDWARD SCHNEBERGER

Biologist, Wisconsin Conservation Department, Sturgeon Bay, Wis.

INTRODUCTION

Within the last few years the smelt, *Osmerus mordax* (Mitchill), has become very abundant in the waters of Green Bay, Lake Michigan. Its establishment in Lake Michigan has been discussed by Hankinson and Hubbs (1922), Creaser (1925), and its present distribution in the Great Lakes is presented in this volume by Dr. John Van Oosten.

Like many exotic species in a favorable new habitat, the smelt have flourished and reproduced so rapidly that at present it is probably the most abundant species in Green Bay. From July to December the smelt are a serious menace to the commercial fishermen operating gill nets, since they become bridled or caught by their mouths to such an extent that the net will catch only a few, if any, of the more desirable species. Smelt caught in this manner are usually badly decomposed before the nets are lifted and consequently are unfit for human food. The fishermen have an unpleasant, unprofitable and tedious task of removing them from their nets. The dentiation of the smelt makes the fishermen's task more difficult because the meshes catch on the teeth making it necessary to pick the strands out of their mouths. This condition has forced the fishermen to cease gill net fishing for part of the season.

FOOD HABITS

The question of the food habits of the smelt grew in importance as their abundance increased. According to Creaser (1925, 1927) the smelt in Crystal Lake, Cold Creek, and Mountain Lake, Michigan, fed upon young perch, lake shiners, and rock bass. One specimen taken from Lake Michigan was found to contain a small whitefish in its stomach. Referring to the smelt of Lake Champlain, Green (1930) wrote: "The smelt are also food for many species of fishes. Other fishes do not escape entirely from the smelts in their turn; but apparently the latter, at least in Lake Champlain are partial to their own kind."

A study of the food habits of this smelt was started in March 1933 and is still underway. Specimens have been examined during every month of the year. Examination of the stomachs of 3,015 smelt showed 1,736 with food. During the spring spawning run of 1934, 300 smelt were examined but only three of these had traces of food showing that the smelt apparently do not feed during the spring run. Of the 1,736 stomachs containing food, 1,339 contained *Mysis*, 192 Amphipoda,

twenty-three *Pisidium,* fourteen Ostracoda, nine *Hexagenia,* three dipterus larvae and forty-three Oligochaeta. The remaining 113 contained fish remains, twenty-one *Cottus,* five *Lota,* thirty-seven smelt and in fifty the fish remains were so nearly digested that specific identification was impossible. From these results it is seen that 6.5 per cent of the smelt containing food had fed on fish. In every series of smelt stomachs examined, *Mysis* was found with great regularity.

Stomach analyses were made on 200 smelt taken within one-fourth to one-half mile of the reefs where approximately 500,000 lake trout fry had been planted two days previously. The trout were planted in water from three to ten fathoms in depth and the smelt were taken in water from fifteen to nineteen fathoms, (the nets in water shallower than fifteen fathoms contained no smelt). In this instance the smelt had eaten *Mysis* and smelt. No lake trout fry were found in the smelt stomachs. This observation is entirely in agreement with Kendall (1926) who, in regard to possible damage to young trout and salmon by smelt stated: ". . ., but under no natural conditions are they a menace to young trout and salmon, for the young of the two species do not occur in the deep-water resort of the smelt, and the smelt is not seeking food when it ascends streams to spawn, where young trout and salmon occur." (p. 316)

Food for Other Species

On the other hand, the smelt are preyed upon extensively by lake trout and to a lesser extent, by perch and burbot. From late April to December, the lake trout in northern Green Bay were found to subsist almost entirely on smelt. Commercial fishermen operating set hooks for trout use smelt as bait successfully. Some state that smelt make a better bait than either small herring or bloaters.

Fecundity and Growth

The smelt in Green Bay spawn at the end of their second year of life and at that time are from six and a half to eight and a half inches in total length. Creaser (1925) reported the Crystal Lake smelt as spawning when two years old and from six and a half to seven and a half inches in total length. The Green Bay smelt have a more rapid rate of growth as may be seen in the accompanying table:

Age of Smelt	*Green Bay*		*Crystal Lake*
Year of Life	*Average Length*	*Range*	
II	7 inches	6½ to 8½ inches	6½ to 7½ inches
III	10 inches	9 to 11½ inches	9 inches
IV	12 inches	11 to 13 inches	10 inches
V	14 inches	14 inches	10¾ to 12 inches

The more rapid rate of growth of the Green Bay smelt may be accredited to a more favorable environment since both populations supposedly originated from the same stock.

The maximum size of smelt found in Green Bay is indicated by the capture, during its fifth year of life, of a female, fourteen inches in total length and weighing eight ounces.

Langlois (1935) calculated that female smelt six and one-fourth to six and one-half inches long yield an average of 25,102 eggs, while a nine-inch smelt produces 43,125 eggs. Last spring (1936) the author collected 962 eggs from the spawning grounds and found 708 or 73.6 per cent of them to contain developing embryos. With this efficiency of reproduction the smelt should have no difficulty in maintaining their numbers in Green Bay.

Commercial Value of Smelt

When the smelt first became abundant in Green Bay, it was feared by many that they would have little or no market value. However, this fear did not materialize. The smelt were in demand on the market except during the summer and the price ranged up to fifteen cents per pound. An average of three or four cents a pound is paid to the commercial fishermen. The low cost of the smelt and their fine flavor were factors that created the demand. Smelt are marketed not only by commercial fishermen, but also by anyone who cares to dip them out of a stream during the spawning run. Although accurate data on the catch by the dip net fishermen are not available, it is readily conceded that they market many more smelt than do the commercial fishermen. It is estimated that during the 1936 spring run 3,250 tons valued at $65,000.00 were taken from the Menominee River at Marinette, Wisconsin.[1] Mr. Clare Farewell, district supervisor for the Michigan Conservation Department, estimated that the streams in Menominee and Delta Counties (Michigan) produced 1,460 tons with a wholesale value of $45,000.00.[2] Both of these estimates show a production nearly double that of the previous year.

According to the monthly reports submitted by commercial fishermen to the Wisconsin Conservation Department more than 500,000 pounds of smelt with an estimated value of $25,000.00, were marketed from January 1 to July 1, 1936 by commercial fishermen operating in Green Bay waters. The present commercial value of this species to the commercial fishermen as a whole may be considered insigficant when compared to the value of the catch of some of the other commercial species. However, the smelt is a newly introduced species and only a small fraction of the commercial fishermen are equipped to catch them in quantity. Pound and drop or fyke nets are used mostly for their capture. Because of the small size of the smelt, the net meshes in impounding nets used for perch and herring proved to be too large and many of the smelt escaped. To the pound nets, the fishermen attached aprons of burlap to the lifting walls of the pot to prevent the escape of smelt during

[1] Green Bay-Press Gazette, Green Bay, Wisconsin, April 24, 1936.
[2] The Fisherman, Grand Haven, Michigan, June, 1936.

the lifting process. In many of the leads and hearts of the impounding nets, the meshes were too large and the smelt would go through the lead rather than follow it and enter the pot or crib. Fishermen operating impounding nets are modifying their gear to take smelt. Recent legislation in Wisconsin permits the use of smaller meshes in pound nets.

The gill net fishermen have been seeking a law that would permit them to use gill nets with a small mesh to take smelt during the winter. These nets have not been legalized because of the possible danger of destroying large quantities of the young of other species, particularly perch. Experimentation (Schneberger and Patterson, 1936) showed that in some areas these small meshed nets could be used without taking perch, but in other areas, approximately fifty per cent of the catch was composed of small perch. Several mesh sizes were used but the most efficient for the taking of smelt were those of one and a half and one and three-fourths inches, stretched measure. The former took more smelt, but the latter took smelt of a larger size that brought two cents more a pound. Legalization of small meshed gill nets for smelt will probably depend upon what plan of regulation can be devised that will protect small perch, herring, etc.

When the smelt fishing and marketing methods are developed to a stage where they are on a basis equal to those of other species, their commercial value may be as great as that of other commercial species, now taken.

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THE INCREASE IN THE ABUNDANCE OF THE YELLOW PIKE-PERCH, *STIZOSTEDION VITREUM* (MITCHILL), IN LAKES HURON AND MICHIGAN, IN RELATION TO THE ARTIFICIAL PROPAGATION OF THE SPECIES

RALPH HILE

Assistant Aquatic Biologist, U. S. Bureau of Fisheries, Ann Arbor, Mich.

INTRODUCTION

One of the most important problems concerning the fisheries of the Great Lakes—a problem whose solution has been too long delayed—is that pertaining to the relative effectiveness of artificial propagation and natural reproduction in the maintenance of the supply of certain commercial species. There are two important reasons for the long delay in solution of the hatchery question. First, the direct solution founded on the comparison of the percentage of fertilization of hatchery eggs and naturally spawned eggs, the relative survival of these eggs up to the time of hatching, and the relative viability of planted and wild fry is confronted with apparently insurmountable technical difficulties. Second, the indirect solution, based on the study of correlations between fry plantings and the abundance of fish in later years has been handicapped not only by the absence of reliable statistical measures of abundance but also by the lack of knowledge as to the number of years that must elapse before fry plantings can be expected to benefit the commercial stock. The technical difficulties persist, but fortunately improved methods of gathering statistics and increased knowledge of the life histories of important species have now made possible an indirect evaluation of the effectiveness of artificial propagation of some species in certain Great Lakes waters. It is the purpose of this paper to present, primarily as an illustration of method, a study of the relationship between the artificial propagation of the yellow pike-perch and recent changes in the production and abundance of this species in four fishing areas within the State of Michigan waters of Lakes Huron and Michigan.

The detailed reports of daily fishing activity that are submitted at the end of each month by every commercial fisherman licensed to fish in the Great Lakes waters under the jurisdiction of the State of Michigan make possible a rather precise estimation of annual fluctuations in the abundance of the different species in the various fishing areas, as these fluctuations are reflected in the catch per net. Both the annual records of the plantings of yellow pike-perch fry in the State of Michigan waters of Lakes Huron and Michigan, and the statistical reports employed to

follow annual fluctuations in abundance in the Michigan waters have been made available through the courtesy of the Michigan Department of Conservation.

In the treatment of the material the historical records of the production of the yellow pike-perch in Lakes Huron and Michigan will be examined first in order to establish the extent of the recent increase in the production of the species. Next, the data on changes in the abundance of yellow pike-perch, beginning in 1929, will be presented in some detail for Saginaw Bay, southern Lake Huron (Port Huron are), Green Bay and southern Lake Michigan (all waters south of Arcadia, Michigan). Finally, these recent changes in the abundance of yellow pike-perch will be examined in relation to changes in the number of fry planted in the four areas.

Although the present study is concerned primarily with fry plantings of yellow pike-perch in 1924 and later years, all available records for earlier years have been examined. Plantings of yellow pike-perch in the State of Michigan waters of Lakes Huron and Michigan prior to 1924 were so small that they could not have had much effect on the abundance of the species in these waters. The only plant made earlier than this date by the State of Michigan was a small one of 1,130,000 fry in Saginaw Bay, 1921. During the period, 1908-1919, the U. S. Bureau of Fisheries planted an average of 4,400,000 fry per year in Saginaw Bay.

Production of Yellow Pike-Perch in Lakes Huron (1912-1935) and Michigan, (1912-1934).

The record of the production of yellow pike-perch in the State of Michigan waters of Lakes Huron and Michigan may be found in Table 1.[1] It is at once apparent that the production of yellow pike-perch during the last several years for which data are available was well above the average in each of the two lakes.

In Lake Huron, the years, 1932-1935, represent the longest period of sustained high production of yellow pike-perch since 1912. These yields of more than a million and a half pounds are unusual, this production having been exceeded only once since 1912 when the largest recorded catch was made in 1918. Three successive large-production years occurred in 1917-1919, and yields of more than a million pounds were produced also in 1915, 1922, 1930.

In Lake Michigan, in contrast to Lake Huron, the recent increase in the abundance of yellow pike-perch in the State of Michigan waters led to an unprecedented production. The yields of both 1933 and 1934 were greater than in any preceding year of the twenty-four-year period, and the 1932 production was exceeded by that of only one year (1916).

[1] The sources of these data are as follows: The catches for Lake Huron, 1912-1933, and for Lake Michigan, 1912-1928, were taken from the reports of the Michigan Department of Conservation and its administrative predecessors. Data for the remaining years were compiled directly from fishermen's reports in the Great Lakes offices of the U. S. Bureau of Fisheries.

It should be emphasized that the increase in the production of yellow pike-perch that began in 1932 occurred simultaneously in Lakes Huron and Michigan.

The data of Table I offer a record of production only and can be taken only as roughly indicative of changes in the abundance of the yellow pike-perch. For the years prior to 1929 there are no adequate records of the fishing effort that led to the listed production. For 1929 and later years it is possible, however, to follow changes in abundance as measured by fluctuations in the catch per net. In the next section of this paper are discussed the changes in the abundance of yellow pike-perch in two fishing areas of Lake Huron during the period, 1929-1935, and two fishing areas of Lake Michigan during the period, 1929-1934.

TABLE 1. PRODUCTION IN POUNDS OF YELLOW PIKE-PERCH IN LAKES MICHIGAN AND HURON, STATE OF MICHIGAN, 1912-1935

Calendar Year	Lake Michigan	Lake Huron	Calendar Year	Lake Michigan	Lake Huron
1912	29,530	398,166	1924	46,164	503,224
1913	15,724	415,992	1925	41,687	457,628
1914	91,539	340,288	1926	58,144	815,721
1915	36,631	1,066,772	1927	24,055	901,401
1916	141,896	845,799	1928	31,832	898,955
1917	83,474	1,146,993	1929	31,088	578,187
1918	42,192	1,903,800	1930	42,303	1,115,001
1919	31,621	1,387,897	1931	50,662	846,972
1920	26,631	844,404	1932	95,475	1,571,206
1921	58,430	724,220	1933	158,960	1,656,929
1922	38,066	1,283,829	1934	156,167	1,602,856
1923	69,013	809,336	1935	.....	1,574,031
Average	.....	.....	.....	60,925	987,067

Changes in the Production and Abundance of Yellow Pike-Perch since 1929. Saginaw Bay

The annual production of yellow pike-perch in Saginaw Bay, the most important fishing area for the species in the State of Michigan, for the years 1929-1935, arranged according to gear is presented in Table 2. (See Fig. 1.) Well over half of the production for the seven-year period was made by shallow trap nets. The percentage of the yellow pike-perch taken in this gear increased regularly from less than thirty per cent in 1929 to almost eighty per cent in 1935. With the exception of 1931, the poundage also increased regularly. The production in the other gears varied irregularly from year to year both as to actual catch and as to the percentage of the total catch for the year. The years of lowest production were 1931 for gill nets and seines, and 1935 for pound nets. The years of highest production were 1932 for gill nets, 1929 for pound nets and 1930 for seines.

The comparison of the annual fluctuations in the production of yellow pike-perch in the different gears with the corresponding fluctuations in the catch per net (Table 3) shows that the changes of both usually proceed in the same direction.[2] In the seines, for example, each increase or decrease in production is accompanied by a change in the same direction in the catch per haul. The other gears, however, show exceptions to this trend. In 1933 gill nets took larger catches per net than in 1932 but had a smaller total production. The trap nets, on the other hand, took less yellow pike-perch per net in 1934 than in 1933, while at the same time the total production increased in 1934. The pound net data have exceptions in 1930 and 1934. In spite of the fact that production and the catch per unit effort commonly change in the same direction from one year to another, the production does not provide a reliable measure of abundance of fish on the grounds fished by a certain gear. As an extreme example it may be pointed out that the production of yellow pike-perch by seines in 1930 was twice that of 1934, although the catch per 100-rod haul was actually the greater in the latter year.

The difference in the average catch per unit effort in different types of fishing gear makes the direct comparison of data based on different types of gear difficult. In order to make a direct comparison possible the fluctuations in the catch per unit effort in each type of gear have been reduced to a percentage basis. The gill net data may be employed to illustrate the procedure. The average catch of yellow pike-perch per thousand linear feet of gill net over the six-year period[3] 1929-1934, was 41.09 pounds. (Table 3.) The comparison of the 1929 average catch of 25.52 pounds per thousand feet of net lifted with the six-year average of 41.09 pounds shows that in 1929 the catch of yellow pike-perch per unit effort was only sixty-two per cent of the six-year average. This percentage is listed in Table 3 under the heading, "Abundance." Similarly the 1930 and 1931 catches of 40.60 and 14.05 pounds were ninety-nine and thirty-four per cent respectively of the six-year average. All the remaining percentages of abundance recorded in the table for the different gears were obtained by the same method.

The detailed discussion of the abundance (percentages) should be preceded by some consideration of the relative degree of reliability of the data based on different types of gear. Of the four gears the shallow trap probably offers the most reliable information, because it produced more than half of the yield of yellow pike-perch and because this species is one of the most important in its catch. The gill net data offer a reliable measure of the relative abundance of yellow pike-perch in the April spawning run. Practically all yellow pike-perch produced by this gear are taken in April, and the recorded catches per unit effort are

[2] The catches per unit effort in Tables 3, 5, 7 and 8 are the number of pounds of yellow pike-perch per 1,000 linear feet of gill net lifted, per single net lift of impounding nets (shallow traps, pounds, fykes), and per haul of a 100 rod seine.

[3] The six-year period was employed because the 1935 data are not yet available for Lake Michigan.

accordingly based on the gill net fishery of this single month. The data from the seine are much less reliable than those from gill nets and trap nets, first, because the seine accounts for only a small part of the total yellow pike-perch production, and, second, because the catch of yellow pike-perch constitutes a relatively unimportant part of the total production of seines.

The pound net data, because of their disagreement with those of other gears, require special consideration. In spite of the fact that pound nets took a fifth of the yellow pike-perch produced in the seven-year period, there is some reason to question the reliability of the estimates of fluctuations in abundance based on this gear. Following the introduction of the deep-water trap net into the region of Lake Huron off Saginaw Bay in 1930 (because of legal restrictions very few deep trap nets were fished in the bay proper) there occurred a pronounced decline in the number of large-mesh pound nets fished. This decline, which entailed the withdrawal from operation of the pound nets that were most effective in the capture of yellow pike-perch, was proceeding most rapidly at the time of the most rapid increase in the abundance of this species. It is believed that this removal of the most effective nets from the pound-net fishery accounts for the discrepancies between the pound net data and those of other gears. Consequently, no high degree of dependence can be placed on the data of abundance computed from the catch of pound nets. However, in the absence of definite proof of the unreliable nature of the pound-net data, they have been included in the computation of average abundance.

The computation of the average abundance for a single year consists of balancing the total catch of the gears included in the analysis against the catch they would have been expected to take had abundance been exactly at the six year average. For example, the computation of the average abundance for 1929 is made as follows:

$$\frac{(116{,}768 + 180{,}131 + 293{,}523 + 31{,}067) \times 100}{\frac{116{,}768}{25.52} \times 41.09 + \frac{180{,}131}{14.56} \times 34.54 + \frac{293{,}523}{17.86} \times 21.12 + \frac{31{,}067}{24.91} \times 52.82} = 60.4.$$

The corresponding computations for the next five years yielded the following percentages:

1930— 87.5	1933—144.8
1931— 55.5	1934—136.5
1932—125.0	

The sum of the six percentages is 609.7. In order that their mean may be 100, each is multiplied by the factor,[4] $\frac{600}{609.7} = 0.984$.

[4] In numerous comptations of this type the "factor" has been found to be so closely about the value, 1,000, that its use probably represents an unnecessary refinement. The correction represents merely an adjustment within the period selected for the establishment of "average" conditions.

With the discussion of the preceding paragraphs kept in mind, it is now possible to estimate the changes in the abundance of the yellow pike-perch in Saginaw Bay over the seven year period, 1929-1935. (Table 3 and Fig. 1.) It should be kept in mind that all percentages have been computed with reference to the six-year average (1929-1934). The 1929 abundance of yellow pike-perch was relatively low (fifty-nine); shallow traps and seines were particularly unsuccessful. In 1930 the catch of all gears except pound nets showed marked improvement, and the general abundance (eighty-six), computed from all gears, rose to within fourteen per cent of average. The catches of all gears fell off so sharply in 1931 that the average abundance (fifty-five) fell below even that of 1929. All gears were so much more successful in 1932 than in 1931, that the general or average abundance rose from fifty-five to 123. This increase continued, although to a lesser degree, in 1933. Three of the gears registered declines in abundance in 1934 and the general abundance fell from 143 to 134. The general abundance dropped again in 1935, but this decrease can be traced entirely to the very poor catches of pound nets. Since, as has been pointed out, there is some question concerning the reliability of the pound-net data, and since the catches of the other three gears all showed improvement, it may be concluded that the abundance of yellow pike-perch in Saginaw Bay was greater in 1935 than in 1934. It is not likely, however, that the 1935 abundance was as great as that of 1933.

A very interesting feature of the data is the close correspondence between changes in total production (Table 2) and general abundance (Table 3). This agreement suggests the possibility that, in some fisheries, production statistics alone may serve as a fairly reliable index of fluctuations in abundance.

TABLE 2. PRODUCTION OF YELLOW PIKE-PERCH IN SAGINAW BAY, 1929-1935

Calendar Year	Production in Pounds by Gear					Total Production
	Large Mesh Gill Net	Shallow Trap	Pound	Seine	All Others	
1929	116,768	180,131	293,523	31,067	10,262	631,751
1930	131,337	434,408	284,102	149,803	4,153	1,003,803
1931	36,051	330,621	183,071	25,098	106,529	681,370
1932	167,945	799,989	224,966	45,113	136,534	1,374,547
1933	108,126	848,248	278,794	91,571	128,033	1,454,772
1934	92,988	951,021	201,233	74,542	29,570	1,349,354
1935	101,393	1,016,324	84,263	75,150	15,549	1,292,679
Percentage	9.7	58.5	19.9	6.3	5.6	100.0

TABLE 3. AVERAGE ANNUAL CATCH PER LIFT OR PER SEINE HAUL OF YELLOW PIKE-PERCH IN SAGINAW BAY, 1929-1935, AND ANNUAL FLUCTUATIONS IN THE ABUNDANCE OF FISH ON THE GROUNDS

Calendar Year	Average Catch per Net or per Seine Haul, in Pounds				Abundance				
	Large Mesh Gill Net	Shallow Trap	Pound	Seine	Large Mesh Gill Net	Shallow Trap	Pound	Seine	Average (General)
1929	25.52	14.56	17.86	24.91	62	42	85	47	59
1930	40.60	26.20	18.23	73.68	99	76	86	139	86
1931	14.05	20.90	12.82	16.14	34	61	61	31	55
1932	57.22	45.84	22.44	43.24	139	133	106	82	123
1933	59.22	52.27	26.72	80.39	144	151	126	152	143
1934	49.94	47.46	28.62	78.58	122	137	136	149	134
1935	53.64	49.18	12.36	86.06	131	142	59	163	130
Average for 1929-1934	41.09	34.54	21.12	52.82	100	100	100	100	100

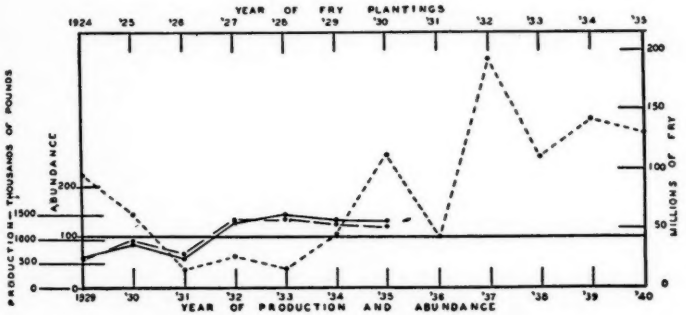

Fig. 1. Production—and abundance—of yellow pike-perch in Saginaw Bay, 1929-1935.

The comparison of the data by periods reveals that in the four years, 1932-1935, the abundance of yellow pike-perch in Saginaw Bay was approximately twice that of the three-year period, 1929-1931. It is this increase that has been so generally considered the result of fry plantings in the area.

Southern Lake Huron

This area includes all State of Michigan waters of Lake Huron south of Forester, Michigan. Eighty per cent of the yellow pike-perch produced in the seven years, 1929-1935, was taken in shallow trap nets and fyke nets (Table 4). Unfortunately, however, the shallow trap-net data

TABLE 4. PRODUCTION OF YELLOW PIKE-PERCH IN SOUTHERN LAKE HURON, 1929-1935

Calendar Year	Production in Pounds by Gear			Total Production
	Shallow Trap	Fyke	All Others	
1929	341	23,384	10,320	34,045
1930	1,650	35,818	6,911	44,379
1931	1,399	53,085	10,793	65,277
1932	5,349	54,535	17,202	77,086
1933	42,063	54,672	11,355	108,090
1934	72,911	42,351	47,354	162,616
1935	132,274	31,252	34,820	198,346
Percentage	37.1	42.8	20.1	100.0

can not well be employed for the estimation of changes in abundance. For all practical purposes the shallow trap-net fishery of the region may be considered to have started in 1933.[5] In this year 31,965 pounds of the listed catch of 42,063 pounds were taken by a single operator in a single month. This phenomenal success in fishing the spawning run (the average lift per net was 266 pounds) accounts for the large value of the average lift of trap nets in 1933 (Table 5). Had this one fisherman not operated during this single month the average lift of yellow pike-perch in shallow trap nets for 1933 would have been eleven pounds. In 1934 and 1935 shallow traps were fished more extensively, by more operators, and over a longer season than in 1933. Consequently, in spite of the continued expansion of the fishery in 1935, the 1934 and 1935 data for the shallow trap can probably be compared.

TABLE 5. AVERAGE ANNUAL CATCH PER LIFT OF YELLOW PIKE-PERCH IN SOUTHERN LAKE HURON, 1929-1935, AND ANNUAL FLUCTUATIONS IN THE ABUNDANCE OF FISH ON THE GROUNDS

Calendar Year	Average Catch per Net in Pounds		Abundance	
	Shallow Trap	Fyke	Shallow Trap	Fyke
1929	2.66	20.80	8	73
1930	10.18	17.91	29	63
1931	12.38	25.62	36	90
1932	20.33	25.78	58	90
1933	122.43	33.38	352	117
1934	40.82	47.85	117	167
1935	58.97	38.49	169	135
Average for 1929-1934	34.80	28.56	100	100

[5] The shallow traps fished in earlier years were largely "gobblers," or small nets with pots usually 4 to 6 feet deep. These nets have a fishing power approximately equal to that of a fyke net, and can not be compared with the true shallow trap.

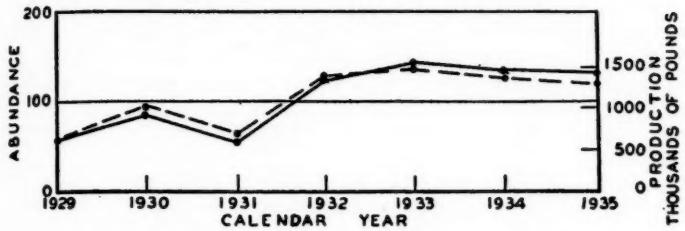

Fig. 2. Production—and abundance (fykes——, shallow traps . . .) of yellow pike-perch in southern Lake Huron, 1929-1935.

According to the fyke-net data the abundance of yellow pike-perch in southern Lake Huron decreased slightly from 1929 to 1930, rose to within ten per cent of the 1929-1934 average in 1931 and remained at this level in 1932, increased rather sharply in 1933 and 1934, and fell off considerably in 1935 (Table 5, Fig. 2). The shallow trap-net data for 1934 and 1935 throw some doubt on the 1935 decline indicated by the fyke-net data. The data as a whole show that there has been a sharp increase in the abundance as well as in the production of yellow pike-perch in southern Lake Huron. This increase resembles closely that observed in Saginaw Bay, although it appears to have occurred a year later in 1933. The production and abundance curves for southern Lake Huron do not show very close agreement.

Green Bay

Data on the production of yellow pike-perch in the State of Michigan waters of Green Bay are presented in Table 6 (Fig. 3). Although the production of this area is not large, it is noteworthy that the relative increase in production was more pronounced here than it was for the corresponding period in Saginaw Bay and southern Lake Huron. In Green Bay the catch of yellow pike-perch in the three year period, 1932-1934, was more than three times that of the years, 1929-1931. The most important gear for the production of yellow pike-perch in the area was the fyke net, followed in order by the pound net and the shallow trap net.

The computations of annual fluctuations in abundance have been based on the catch per unit effort of the three types of nets just mentioned. (Table 7, Fig 3). The abundance percentages for the two leading gears, pounds and fykes, agree rather well, but the data for both of these types of net disagree with those of the shallow trap. This disagreement is particularly prominent for the 1931 and 1934 data. No plausible explanation of the discrepancies presents itself. It should be remembered, however, that the shallow trap net produced only a small part of the

TABLE 6. PRODUCTION OF YELLOW PIKE-PERCH IN GREEN BAY, MICHIGAN, 1929-1934

Calendar Year	Production in pounds by gear				Total Annual Catch
	Shallow Trap	Pound	Fyke	All Other	
1929	7,244	7,171	6,557	5,991	26,963
1930	5,036	6,294	12,646	3,470	27,446
1931	5,379	13,876	19,543	2,671	41,469
1932	7,929	29,586	44,768	2,776	85,059
1933	17,538	36,687	52,546	1,339	108,110
1934	17,239	25,916	61,182	3,910	108,247
Percentage	15.2	30.11	49.6	5.1	100.0

TABLE 7. AVERAGE ANNUAL CATCH PER LIFT OF YELLOW PIKE-PERCH IN GREEN BAY, MICHIGAN, 1929-1934 AND ANNUAL FLUCTUATIONS IN THE ABUNDANCE OF FISH ON THE GROUNDS

Calendar Year	Average catch per net in Pounds			Abundance			
	Shallow Trap	Pound	Fyke	Shallow Trap	Pound	Fyke	Average (General)
1929	3.71	10.80	15.43	40	57	43	47
1930	4.55	7.39	20.17	49	39	56	50
1931	10.21	10.96	27.27	109	58	76	73
1932	9.85	19.60	37.00	105	103	103	106
1933	19.20	33.27	56.56	205	175	157	174
1934	8.61	31.76	59.34	92	168	165	150
Average	9.36	18.96	35.96	100	100	100	100

total yellow pike-perch catch. It is also true that this species constitutes a relatively unimportant part of the total catch of shallow traps. Consequently, the shallow trap-net data may be considered less reliable than data based on pound-net and especially fyke-net catches. The small catches of yellow pike-perch in trap nets in 1934 account in large measure for the drop in the general abundance of the species in that year.

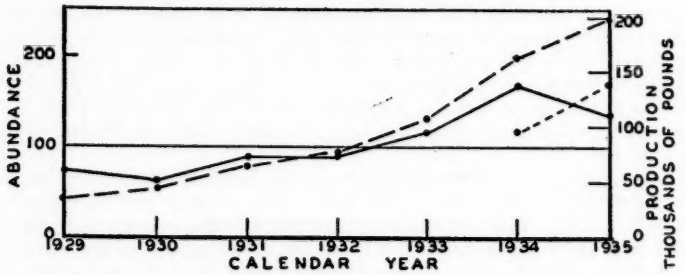

Fig. 3. Production—and abundance—of yellow pike-perch in Green Bay, 1929-1934.

The comparison of the changes in the abundance of yellow pike-perch in Green Bay with those of Saginaw Bay over the same period of time brings out a close resemblance between the two sets of data. A recent pronounced increase in abundance occurred simultaneously in these two widely separated areas. This increase in abundance was relatively the greater in Green Bay. The Green Bay data resemble the Saginaw Bay data in showing a close agreement between fluctuations in production and general abundance.

Southern Lake Michigan

This area includes all State of Michigan waters of Lake Michigan south of Arcadia, Michigan (ten miles south of Frankfort). Data on both production and abundance of yellow pike-perch in the region for the years, 1929-1934, may be found in Table 8. (Fig. 4). The total production of yellow pike-perch in this region was small throughout the six-year period, but the relative increase in production in the more recent years was very large. The catch of yellow pike-perch in the three years, 1932-1934, was more than four and one-half times that of 1929-1931. In spite of the inclusion of the poor year, 1932, this is the largest relative increase in production found in any of the four areas considered.

The pound net was the only type of gear that took yellow pike-perch in sufficient quantities to serve as a basis for the estimation of annual fluctuations in abundance, and even in this gear the production was so small that the data must be recognized as indicative of trends rather than descriptive of detail. The data for 1929 were included only for the sake of completeness. In spite of the criticisms to which the abundance data are subject, they serve to show conclusively that the large increase in the production of yellow pike-perch in 1933 and 1934 was accompanied by a large increase in the abundance of the species.

It should be noted that southern Lake Michigan and southern Lake Huron agree in showing a pronounced upturn in the abundance of yellow pike-perch in 1933, a year later than in Saginaw Bay and Green Bay.

TABLE 8. PRODUCTION AND CHANGES OF ABUNDANCE OF YELLOW PIKE-PERCH IN SOUTHERN LAKE MICHIGAN, 1929-1934

Calendar Year	Production in Pounds by Gear			Average Catch in Pounds	Abundance
	Pound	All Others	Total	Pound Nets	Pound Nets
1929	866	1,132	1,998	11.55	71
1930	10,616	2,918	13,534	12.79	79
1931	5,252	1,314	6,566	7.20	45
1932	7,925	1,638	9,563	9.00	56
1933	41,565	4,686	46,251	27.71	171
1934	33,210	12,464	45,674	28.85	178
Percentage	80.5	19.5	100.0	16.18*	100*

* Average

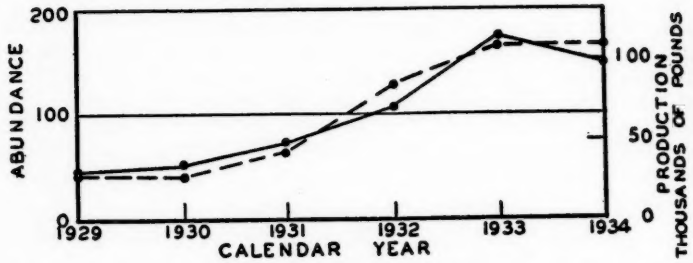

Fig. 4. Production—and abundance—of yellow pike-perch in southern Lake Michigan, 1929-1934.

Fry Planting and Changes in Abundance

In the preceding pages it was established definitely that the recent increase in the production and abundance of the yellow pike-perch was by no means confined to Saginaw Bay, the chief production center for the species in the State of Michigan waters of the Great Lakes. Equally pronounced relative increases in both production and abundance occurred simultaneously in southern Lake Huron, Green Bay, and southern Lake Michigan. This situation has been generally overlooked since the production and abundance of yellow pike-perch in regions other than Saginaw Bay were always so small that even a large *relative* increase in abundance did not raise this species to a position of importance in the fishery. The fact that the increase in abundance was general rather than local suggests strongly that the causes operative in the different areas may have been the same.

There exists a rather general belief, particularly among commercial fishermen, that the increase in the abundance of yellow pike-perch in Saginaw Bay is the direct result of the artificial propagation of the species. It is probable, however, that this belief is based largely on the concomitant increase in production and artificial propagation, without due regard for the necessary period of time that must elapse before fry plantings can be expected to affect the commercial stock. For example, an article entitled, "Pickerel Propagation in Saginaw Bay," (Great Lakes Fisherman, June, 1936) contains the following statement: "..... it is significant for the fishermen to note that the amount of fish produced is directly proportional to the number of spawn planted each preceding year." This statement carries the obviously absurd implication that the yellow pike-perch of Saginaw Bay attains the legal size of one and one-half pounds within a single year. Certainly, any correlation between fry plantings and the commercial catch must include consideration of the time actually necessary for fry to grow to fish of legal size.

It is the purpose of this section to examine the recent changes in the abundance of yellow pike-perch in relation to the extent of the fry plantings that may reasonably be expected to have contributed to the changes. From records of age determinations on Saginaw Bay pike-perch on file in the Great Lakes offices of the Bureau of Fisheries it was determined that legal size is attained in approximately five years (in the sixth year of life). The age at which the yellow pike-perch attains legal size in other localities of Lake Huron and Michigan probably does not vary more than a year from that of the Saginaw Bay fish.[6] Although the effects of fry planting may be expected to show up first after a lapse of five years, these effects might carry over for one or two or even more additional years.

Saginaw Bay

Data for the examination of the relationship between fry plantings and the abundance and production of yellow pike-perch in Saginaw Bay are presented in Table 9 and shown graphically in Fig. 5. The arrangement is such that each fry planting may be compared directly with the abundance and production five years later.

The examination of Table 9 and Fig. 5 reveals little to support the belief that the recent increase in the abundance of yellow pike-perch has resulted from artificial propagation. The fry plantings dropped from ninety-four million in 1924 to sixty-one million in 1925, but the abundance of yellow pike-perch increased from fifty-nine in 1929 to eighty-six in 1930. This increase might well be explained, however, as the result of two successive large plants (1924 and 1925). It would appear, however, that the effects of neither the 1924 nor 1925 catch extended to the 1931 season, for with the reduction of the plant to fifteen million fry in 1926 the abundance of fish in 1931 dropped to the low value of fifty-five. The fry plants continued to be small in both 1927 and 1928, but nevertheless, the abundance of yellow pike-perch increased tremendously in 1932 and 1933. The numbers of fry planted were increased in 1929 and 1930, but the abundance of yellow pike-perch declined slightly in 1934 and possibly in 1935. (See p. 14). These correlations, far from supporting the belief that artificial propagation increases the abundance of the stock, tend to show an inverse relationship between the numbers of fry planted and the abundance of fish in later years. If this extreme interpretation is not acceptable, it must be admitted, at least, that the evidence does not point toward any beneficial effects of fry planting.

It may be argued, of course, that the maximum effect of fry plantings appears a year or so later than the year in which the fish reach legal size. This argument has no effect on the conclusions of the preceding

[6] The belief that the growth of the yellow pike-perch does not vary widely in different Great Lakes areas is supported by the fact that the yellow pike-perch of Lake Erie attains a weight of twenty-four ounces in about five years. (Deason, H. J., MS., Morphometric and Life History Studies of the Pike-Perches (Stizostedion) of Lake Erie.

paragraph, for the rearrangement of the data of Table 9 with six or seven years as the interval would not change the conclusion that high abundance was correlated with small fry plants.

Unquestionably it would be most desirable to have data of the type presented in Table 9 and Fig. 5 covering a period of more than six years. With the passage of time this extension of the data will be possible and the blank spaces of the table and figure will be filled. If artificial propagation has any important effect on the abundance, it may be expected that the large fry plantings of 1931-1935 will lead to a sustained high abundance of yellow pike-perch through the period, 1936-1940. Should the abundance decline to a low level within this period the inescapable conclusion will be that fry plantings have no significant effect on the abundance of the commercial stock.

TABLE 9. RELATIONSHIP BETWEEN FRY PLANTINGS AND THE ABUNDANCE AND PRODUCTION OF YELLOW PIKE-PERCH IN SAGINAW BAY

Fry Plantings		Abundance and Production		
Year	Number*	Abundance	Production†	Year
1924	94	59	632	1929
1925	61	86	1,004	1930
1926	15	55	681	1931
1927	26	123	1,375	1932
1928	15	143	1,455	1933
1929	45	134	1,349	1934
1930	112	130	1,293	1935
1931	43			
1932	191			
1933	110			
1934	140			
1935	130			

* Millions of fry
† Thousands of pounds

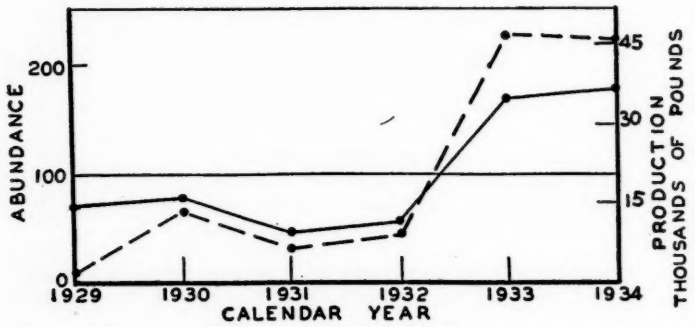

Fig. 5. Relationship of fry plantings——, abundance——, and production—— of yellow pike-perch in Saginaw Bay.

Southern Lake Huron

Since there are no records of pike-perch plantings in southern Lake Huron, the recent increase in the abundance of yellow pike-perch in this region (Table 5) represents nothing more than a natural fluctuation in abundance. Any contention that the waters received benefits from Saginaw Bay plantings by means of migration loses force by reason of the strong evidence that Saginaw Bay, itself, did not benefit from these plantings.

Green Bay

The only record of a yellow pike-perch plant in the Michigan waters of Green Bay is that of 1,500,000 fry planted in 1930. Even if it is assumed that this single small plant might affect the abundance of the yellow pike-perch in the region, it must be recognized that the introduction occurred too late to play any part in the recent increase in the abundance of the species. The increase, then, must be considered to represent only a natural fluctuation. It is of particular importance to note that the increase in abundance in Green Bay, which is wholly traceable to natural causes, is relatively more pronounced than the increase that occurred in Saginaw Bay, the center of artificial propagation activities.

Southern Lake Michigan

Although there are no records of yellow pike-perch plantings in the waters of southern Lake Michigan numerous plants have been made in tributary rivers and in inland lakes with direct communication with Lake Michigan. The probability that the fry from these relatively small plantings found their way into Lake Michigan in sufficient numbers to account for the recent increase in the abundance of yellow pike-perch in the region is remote. Nevertheless, in the interest of a thorough anaylsis, a comparison of these plantings with the changes in abundance in southern Lake Michigan is presented in Table 10. The data of this table do not indicate that fry plantings in tributary waters had any effect on the abundance of the yellow pike-perch in southern Lake Michigan. On the contrary, the high abundance of 1933 and 1934 occurred at a period when a decline in abundance would be expected.

The argument for the effectiveness of artificial propagation might be improved by extending the assumed period of time necessary for the fish to reach commercial size to six or seven years. Even this improved argument does not stand up well before the opposing arguments that the fry plantings were very small, and that they were not actually made in Lake Michigan. Another argument against the explanation of the 1933-1934 abundance as the result of fry plantings lies in the fact that the 1925-1927 plantings were no larger than those

made in most of the earlier years, but often were smaller. For example, the average numbers of fry planted per year by the State of Michigan in waters tributary to southern Lake Michigan by 6-year periods were: 1918-1923, 527,000 fry; 1912-1917, 502,000 fry; 1906-1911, 977,000 fry. These earlier plantings were probably not very effective, for an examination of Table 1 shows that in many of these earlier years the production of all Lake Michigan, including Green Bay, was less than the production of southern Lake Michigan alone in 1933 or 1934. The logical conclusion, therefore, appears to be that in southern Lake Michigan as in Saginaw Bay, southern Lake Huron, and Green Bay the recent increase in the abundance of the yellow pike-perch represented only a natural fluctuation.

This agreement of the results for all four areas leads to the conclusion that the recent general increase in the abundance and the production of yellow pike-perch in the State of Michigan waters of Lakes Huron and Michigan represented a natural fluctuation in abundance, and did not have its origin in the artificial propagation of the species.

TABLE 10. RELATIONSHIP BETWEEN THE ABUNDANCE AND PRODUCTION OF PIKE-PERCH IN SOUTHERN LAKE MICHIGAN AND THE PLANTINGS OF FRY IN TRIBUTARY WATERS

Fry Plantings		Abundance and Production		
Year	Number*	Abundance	Production†	Year
1924	....	71	2	1929
1925	375	79	14	1930
1926	320	45	7	1931
1927	950	56	10	1932
1928	....	171	46	1933
1929	....	178	46	1934
1930	....			
1931	722			
1932	2,340			
1933	4,900			
1934	2,885			

* Thousands of fry
† Thousands of pounds

Summary

1. Attention is called to the importance of the problem concerning the effectiveness of artificial propagation and fry planting for the maintenance of the stock of commercial species of fish in the Great Lakes waters.

2. A method is proposed for the solution of the problem by means of a comparison of the known quantities of fry planted in different years with fluctuations in the abundance of fish in later years. The fluctuations in abundance are determined from the analysis of commercial fisheries statistics.

3. The specific application of the method to the yellow pike-perch

leads to the conclusion that the recent general increase in the abundance of this species in the State of Michigan waters of Lakes Huron and Michigan was not the result of artificial propagation, but, rather, represented a natural fluctuation in abundance.

Discussion

Mr. Lester Smith (Wisconsin): The fishing for yellow pike has been in the region of Saginaw Bay. I was told that the large percentage of this spawn was sent to inland waters of the lakes. Are you taking that into consideration?

Dr. Hile: In earlier years, yes, practically all, but to-day the percentage to inland lakes would be negligible in proportion to the total amount of production. The plantings in recent years have been running in the neighborhood of a couple of hundred million fry; I think you will find that the inland lakes do not get any quantity approaching that at all.

Mr. Lester Smith: Wisconsin only, up to the last year, has required compulsory reports on the part of the fishermen. What sources of information did you go to for your statistics on Green Bay and lower Lake Michigan?

Dr. Hile: I intended to make that clear. Southern Lake Michigan, the west part of the lake south of Arcadia, is the region I took, down to the Indiana line.

Mr. Lester Smith: Green Bay waters are largely in Wisconsin.

Dr. Hile: Wisconsin does not produce pike perch.

Mr. Lester Smith: Not very many.

Dr. Belding: Has Dr. Hile figures back far enough to determine whether there is an any cyclic trend in quantities of fish in the lake? These figures are rather striking, as they run practically parallel to the cyclic trends in the Atlantic salmon.

Dr. Hile: In trying to work out cycles in the Great Lakes we are handicapped by having nothing more than production statistics, and production statistics are in no sense a certain measure of the abundance of fish. Certain cycles have occurred but there are economic factors that we know have intervened. For example, in western Lake Erie there was a large production of fish during the bitterest years of the depression, but the abundance underwent practically no change, which simply meant that a lot of people were in a bad way financially and were doing no fishing. As industrial conditions in that region improved, production went down. I think it is a very delicate proposition to try to measure abundance merely through production.

THE DISPERSAL OF SMELT, OSMERUS MORDAX (MITCHILL), IN THE GREAT LAKES REGION

JOHN VAN OOSTEN

In Charge, Great Lakes Fishery Investigations
U. S. Bureau of Fisheries, Ann Arbor, Mich.

The phenomenal spread of the introduced smelt, *Osmerus mordax* (Mitchill), throughout the Great Lakes region during the past decade will be referred to repeatedly in the years to come as another classic example illustrating the many complications that follow the successful establishment of an exotic species of fish. Whether the smelt will ultimately prove to be a curse or a blessing to the Great Lakes States I can not say. It has been a source of considerable profit for many communities located near smelt waters but it likewise has been a source of great hardship for those commercial fishermen whose nets have been fouled by the entangled fish or whose fishing grounds have been invaded by hordes of these fish. Fishery administrators and the fishing industry alike have watched the spectacular spread of the smelt in the Great Lakes with considerable apprehension since the effect of a dense population of smelt on the valuable native species of fish is still an unsolved problem.

Because the smelt has become already a problem of major proportions on the Great Lakes and will soon demand the concerted and whole-hearted attention of state, provincial and federal governments, it is important that a detailed record of the history of the spread of the smelt throughout the Great Lakes area be completed and preserved in permanent form. There are presented herewith in summary form in chronological order and by Great Lakes drainages the date of first apparance or of first runs of smelt at various localities, together with brief notes on abundance and other items of interest and the source of the record. The original unpublished sources were consulted whenever possible and in addition to these the published references have been listed also. The Department of Conservation of the State of Michigan is responsible for most of the original records, which were obtained largely by the conservation officers in the field. To Mr. Fred A. Westerman of the Michigan Department of Conservation I am deeply indebted for his splendid cooperation in providing copies of most of the original reports and in checking my preliminary list of records. I am indebted also to Dr. Carl L. Hubbs of the Museum of Zoology, University of Michigan, and Dr. A. S. Hazzard, Director of the Michigan Institute for Fisheries Research, for permission to use the files of their respective organizations. To the Game and Fisheries Department of Ontario, the Conservation Department of Wisconsin, and Prof.

William J. K. Harkness of Toronto I am indebted for cooperation in checking my tentative list of records and in furnishing new records. Dr. H. J. Deason of the Bureau's staff at Ann Arbor, Michigan, drew the map and plotted the stations.

Although several shipments of smelt eggs have been deposited in various waters of the Great Lakes region, a single one, that planted in Crystal Lake, Benzie County, Michigan, is considered the source of all the smelt now found in the Great Lakes, except Lake Ontario. The first shipment of smelt into the State of Michigan or perhaps the upper Great Lakes area was made in the spring of 1906 when a small consignment of smelt eggs from New England was received by the Sault Ste. Marie hatchery and deposited in the St. Mary's River to provide food for the land-locked or sebago salmon that had been planted in this river for several consecutive years. In 1909, 1914, 1916 and 1921 an additional 37,700,000 smelt eggs were deposited in this river. (400,000 eggs, not 2,000,000 as stated by Creaser (9), were received by the Fish Commission in 1921.) The other plants of smelt eggs recorded for Michigan are as follows:

1912—April 4, Torch Lake, Antrim County	6,000,000
April 6, Crystal Lake, Benzie County	16,400,000
1914—Huron Mt. Club, Big Bay (probably planted in Mountain Lake, Howe Lake and/or Trout Lake)	2,000,000
1915—Weesh-Ko-Wong Trout Hatchery, Williamsburg	4,500,000
1916—Weesh-Ko-Wong Trout Hatchery, Williamsburg	2,000,000
Huron Mt. Club, Big Bay (probably planted in Mountain Lake, Howe Lake and/or Trout Lake)	2,000,000
1921—Huron Mt. Club, Big Bay (probably planted in Mountain Lake, Howe Lake and/or Trout Lake)	200,000
March 30, Sturgeon River Power Pond, Wolverine (Received from Cold Spring Harbor Hatchery, New York)	200,000

Apparently none of these introductions was successful except those of Crystal Lake, Howe Lake and Trout Lake.

From the records of dispersal it may be seen that although the smelt was introduced into Crystal Lake in 1912, the species was not observed until the spring of 1918. In 1923 it was first taken in Lake Michigan off the east shore near Frankfort, Michigan, and by 1924 it had crossed the lake and reached Big Bay de Noc, an arm of Green Bay. In 1925 it was reported in northern Lake Huron off Rogers City, Michigan, and two years later (1927) further south in Thunder Bay. The next year, 1928, it reached Saginaw Bay and in 1930 the Canadian waters of Lake Huron of Tobermory in Georgian Bay and the St. Mary's River, the outlet of Lake Superior. By 1932 the smelt had migrated to the southernmost end of Lake Huron (Port Huron, Michigan) and even entered the St. Clair River and Lake St. Clair. In 1935 it reached the extreme eastern end of Georgian Bay where the first spring run (Hog River) occurred in this Bay. In 1936 a specimen was taken off

Cape Croker, Ontario. Recently I was surprised by receiving specimens taken off Vermillion, Ohio, from the warm shallow waters of western Lake Erie. Later reports indicated that the smelt had already invaded Lake Erie (Port Dover, Ontario) in 1935 and had also been taken in the island region in western Lake Erie in April, 1936. The most eastern record for the United States waters of Lake Erie is Ashtabula, Ohio. Thus, at the present time the smelt is found in various degrees of abundance in the St. Mary's River, North Channel, Georgian Bay, the Michigan waters of Lake Huron proper, the St. Clair River, Lake St. Clair, and Lake Erie. Peculiarly enough, it has not yet been reported for the Canadian waters of Lake Huron proper.

Although the first smelt recorded for the west shore of Lake Michigan was taken in 1924 the species was not observed in the Wisconsin waters of Green Bay until 1928. In 1929 a few smelt were taken in Lake Michigan off Gills Rock, Wisconsin, and the Sturgeon Bay canal. In 1930 the species had reached Manitowoc, Port Washington and Racine, all in Wisconsin, and in 1931, Kenosha, Wisconsin, and Michigan City, Indiana. The smelt was probably present also at Waukegan, Illinois, although it was not reported for this locality until 1936. For some reason the southern migration along the east shore lagged behind that of the west or Wisconsin shore. It was not until 1932 that the smelt moved south along the Michigan shore and were taken off Manistee and at Newaygo on the Muskegon River (via Muskegon). It took the species another four years (1936) to reach Allegan on the Kalamazoo River (via Saugatuck) and St. Joseph, Michigan. It may be concluded that the smelt has now occupied in various degrees of abundance all the suitable waters along all the shores of Lake Michigan. It is particularly abundant in Green Bay where its presence has created special problems in connection with the commercial fisheries. The invasion of Lake Michigan, in contrast to the other Great Lakes, has been completed.

Although the smelt has not yet become a problem in Lake Superior, it has been taken in widely separated localities. In 1930 it was first reported in Whitefish Bay at the eastern end of the lake. In 1934 a specimen was taken off Marquette, Michigan, and in 1936 in Keweenaw Bay, the most western record for the Great Lakes species at the present time. It is believed that the smelt reached Lake Superior through the St. Mary's River rather than from the inland lakes of the Huron Mt. region, although it is perhaps possible for the species to reach Lake Superior from these inland lakes.

With respect to the bathymetric distribution of the smelt in the Great Lakes, records would seem to indicate that except during the spawning season the species lives in waters that range from eight to thirty-five fathoms in depth and is most abundant in water with depths of ten to twenty fathoms.

The records likewise suggest that about five years after the smelt

is first reported present in a locality the first runs are reported for nearby streams or the smelt is reported abundant. With respect to reports of abundance in the open lake the time interval for five localities averaged four and six-tenths years. With respect to first runs the time interval for six ports located on or near suitable streams in the bays of the Great Lakes averaged five years and for four ports located near streams on the open lake it averaged four and seventy-five hundredths years. The close agreement between these three averages indicates that on the whole the records of first appearances are fairly accurate.

Records of the Dispersal of Smelt, Osmerus Mordax, in the Great Lakes Region

The data are given for each year and for each Great Lakes basin in the following order: Locality, number in parenthesis designating the locality on the map, date or season, remarks, number in parenthesis designating the source, letter R indicating that record is based on reliable authority or letter S showing that record is based on a specimen, the number preceding S indicating the number of specimens taken. When localities refer to lakes and streams the name of the county is given also. All specimens have been deposited in the Museum of Zoology, University of Michigan (U. of M.) unless otherwise stated.

Records for 1918

LAKE MICHIGAN BASIN.—Crystal Lake, Benzie County, Michigan (1); spring; eggs introduced in 1912; first run from Crystal Lake into Cold Creek was observed by a resident at Beulah; runs have occurred each year since 1918; (31) R.

Records for 1922

LAKE MICHIGAN BASIN.—Crystal Lake, Benzie County, Michigan (1); spring; first Great Lakes smelt scientifically identified; taken from the Cold Creek run and received by U. of M. May 15, 1922; this specimen was erroneously reported by Hankinson and Hubbs (34) as having been taken from Grand Traverse Bay; (9, 16, 104) 1 S.

Records for 1923

LAKE MICHIGAN BASIN.—Frankfort, Michigan (2); April 25; first specimen received by U. of M. from Great Lakes waters; taken in commercial gill nets five miles south of Frankfort and one and one-half miles from shore; Creaser (12) erroneously reported the first specimen as having been taken in 1925; about April 27, 1925, another specimen was taken in chub nets off Frankfort; smelt was fairly abundant by 1928; (9, 10, 14, 104) 2 S. **Northport Point, Michigan** (3); July 15; specimen reported taken about July 15 in Grand Traverse Bay in 180 feet of water; (9, 38) R.

Records for 1924

LAKE MICHIGAN BASIN.—Big Bay de Noc, Delta County, Michigan (4); March; first specimen from Green Bay waters received by U. of M. March 20; taken in commercial whitefish nets; smelt were abundant in 1930; extensive runs developed in the tributaries in 1931; in July-September, 1931, smelt averaging five and one-half inches in length (probably 1930 year-class) appeared in tremendous numbers; (9, 53, 63, 90, 104) 1 S. **Manistique, Michigan**; March 7; report sent in with above Big Bay de Noc specimen; (37, 104) R.

LAKE SUPERIOR BASIN.—Trout Lake, Marquette County, Michigan (5); August 26-27; scarce; Hubbs took only one specimen, July 8-9, 1927; eggs probably introduced in 1914, 1916 and/or 1921; Creaser erroneously reported egg-plantings in 1918 in Trout and Howe Lakes; (9, 36, 78, 104) 4 S. **Howe Lake, Marquette County, Michigan (6);** August 29; abundant; first seen in 1923; eggs probably introduced in 1914, 1916 and/or 1921; (9, 14, 36, 78, 104) 84 S.

Records for 1925

LAKE HURON BASIN.—Rogers City, Michigan (7); November; first report for Lake Huron; single specimen taken in commercial nets in twenty fathoms; last two sources give no date or other details; (48, 87, 89) R.

Records for 1927

LAKE MICHIGAN BASIN.—Lake Charlevoix, Charlevoix County, Michigan (8); winter, a few taken through ice in winter of 1927-1928 and greater numbers in 1929; runs started in tributaries as follows: Porter Creek and Stover Creek, March, 1929; Boyne River, Horton Creek, Jordan River, Deer Creek, Brown Creek, March, 1930; (39, 50, 51, 52, 88, 89, 104) R (1927); many S (1930). **Empire, Michigan (9);** June 10; first specimen received was taken in a 4¾-inch mesh gill net in twenty fathoms; ten specimens were taken in the spring of 1928 in 20-25 fathoms in whitefish gill nets; (10, 12, 104) 11 S.

LAKE HURON BASIN.—Alpena, Michigan (10); August 27; two smelt taken by Michigan Patrol Boat in 2¾-inch mesh gill nets from ten fathoms in Thunder Bay; smelt also reported in 1928 and 1930; first and heavy Thunder Bay River run started on April 8, 1932; specimens taken below dam at Alpena; (1, 13, 39, 49, 64, 87, 89, 104) R (1927); 5 S (1932).

LAKE SUPERIOR BASIN.—Mountain Lake, Marquette County, Michigan (11); July 6-10; scarce; eggs probably introduced in 1914, 1916 and/or 1921; (11, 36, 104) 39 S.

Records for 1928

LAKE MICHIGAN BASIN.—Suttons Bay, Leelanau County, Michigan (12); July; original source not seen; also in Grand Traverse Bay but sources give no details (39, 89); in December, 1931, Bauer, commercial fisherman, had to remove his 5½-inch mesh gill nets set for trout in Omena Bay reporting that smelt were taken with every lift and seemed to be all over the Bay but mostly on the trout spawning ground; smelt taken in as deep as thirty-five fathoms; in 1935 first runs in Weaver, Belanger, Deuster and Leo Creeks, Leelanau County; (7, 10) R. **Traverse City, Michigan (13);** July; west arm of Grand Traverse Bay; original source not seen; source (10) gives no details; (10) R. **Charlevoix, Michigan (14);** July; fairly abundant in Lake Michigan; (10, 12) R. **Green Bay, Wisconsin and Michigan (15);** first smelt observed in Wisconsin waters were taken in gill nets near Little Sturgeon Bay, Door County, in 1928 when only a few were caught; smelt were very abundant in 2¼-inch gill nets under ice off Menominee, Michigan, during February-April, 1931, and common off Oconto, Wisconsin, in April, 1931, averaging eleven inches in length (probably 1927 year-class); in 1931 (July and later) the smelt averaged five and one-half inches (probably 1930 year-class) and ran twenty to a pound and were very abundant throughout Green Bay from east of Oconto, Wisconsin, north to Washington Island, Wisconsin; small runs started in 1930 and extensive runs in 1931; (56, 63, 90, 110) R.

LAKE HURON BASIN.—Rockport, Michigan (16); winter; some taken in chub nets in winter of 1927-28; first two sources give no date or other details; (87, 89, 107) R. **Saginaw Bay, Michigan (17);** original source not seen; source (39) gives no details; first specimen received by U. of M. taken April 29, 1930, off Sebewaing, Michigan; (28, 39, 87, 89, 104) R (1928); 1 S (1930).

Records for 1929

LAKE MICHIGAN BASIN.—Gills Rock, Wisconsin (18); a few caught in gill nets in Lake Michigan; (24) R. **Menominee, Michigan**; a few appeared in Green Bay; (63) R. **Sturgeon Bay, Wisconsin** (19); a few caught in gill nets off canal in Lake Michigan; (24) R.

Records for 1930

LAKE MICHIGAN BASIN.—Naubinway, Michigan (20); winter; taken in whitefish nets during winter of 1930-31; only a few taken in nets in 1931; (62, 63) R. **Springer Creek, Menominee County, Michigan; March 27**; five and one-half miles north of Menominee, Michigan; big run started but lasted only one and one-half days; (56) R. **Door County streams, Wisconsin**; spring; first runs started as follows: In 1930 in Sugar Creek, three miles south of Little Sturgeon Bay, and in some small streams flowing into this Bay; in 1932 in Big Creek and Little Creek emptying into Sturgeon Bay; in 1933 from Lake Michigan into Stoney Creek near southern boundary of Door County; in 1934 in Hibbards Creek at Jacksonport and in South Creek flowing into Whitefish Bay, Lake Michigan; (110) R. **Manitowoc, Wisconsin** (21); April; taken in fyke net in late April; (87, 89, 104) 1 S. **Port Washington, Wisconsin** (22); July 5; first specimen taken in a herring pound-net and identified by me in the field but not preserved; on June 15, 1931, a second specimen sent to me and preserved was taken in a herring pound net, two miles north of the port; in the fall of 1931 nearly every lift contained smelt; a small spring run started up Sauk Creek at Port Washington in 1933; in June, 1934, anglers were catching hundreds of smelt off the docks with hook and line; in July, 1935, perch were feeding on smelt about three inches long; (40, 41, 97, 98, 99, 100, 101) 1 S. **Racine, Wisconsin** (23); taken in commercial gill nets; (55, 105) R.

LAKE HURON BASIN.—Cheboygan, Michigan (24); spring; taken in commercial nets; Creaser erroneously reported 1931 as the year of first appearance; a good run started in Cheboygan River, April 11, 1936; (5, 13, 87, 89, 112) R. **St. Mary's River, Chippewa County, Michigan** (25); original source not seen; source (89) gives no details; in 1935 a run occurred at Sault Ste. Marie; (4, 78, 89) R.

LAKE SUPERIOR BASIN.—Whitefish Bay, Chippewa County, Michigan (26); original source not seen; source (112) gives no details; Creaser wrote in 1932, "the smelt has not as yet been taken from Lake Superior"; Lomoe reported that smelt first appeared in commercial nets in 1934; others (33, 36a, 40, 41, 78) also reported smelt in the Bay; (13, 112) R.

Records for 1931

LAKE MICHIGAN BASIN.—Northern Lake Michigan streams; spring; runs developed all along the Upper Peninsula shores of the State of Michigan; source gives no names of streams; (90) R. **Petoskey, Michigan,** (27); April 3; first run into Bear River at Petoskey; twelve specimens received by Michigan Department of Conservation; (13, 29, 60, 61, 90, 104) 4 S. **Cecil Bay and Big Stone Bay, Emmet County, Michigan** (28); winter; west of Mackinaw City; first Carp River run (from Cecil Bay) occurred in spring; (90) R. **Brevort, Michigan** (29); February 4; some taken in every lift of herring nets; (54) R. **Little Bay de Noc, Delta County, Michigan** (30); February; smelt averaging five and one-half inches were very abundant during July and later; large runs in all of its tributaries in 1932; (15, 63, 67) R. **Peshtigo Harbor, Marinette County, Wisconsin** (31); March 14-21; about 7,800 pounds taken in herring nets; large run into Peshtigo River; (59, 63, 108) R. **Kenosha, Wisconsin** (32); January 24; specimen taken SE of Kenosha Harbor in thirty fathoms by a commercial gill net; six specimens

were reported taken in a gang of gill nets, December 5, 1932 (Van Oosten); (13, 90, 104) 1 S. **Michigan City, Indiana** (33); about 1931 a few smelt were taken in 2½-inch mesh chub nets in eighteen fathoms; averaged about one-third pound; have been increasing since; in fall of 1935 chub nets in 15-20 fathoms took several large and about five pounds small smelt about eight inches long in each life; none taken in deeper water, harbor, or streams; (43) R.

LAKE HURON BASIN.—St. Ignace, Michigan (34); March 22; specimens taken from bay; in 1936 about 150,000 lbs. shipped; (13, 58, 84, 90, 104) 5 S. **Duncan Bay, Cheboygan County, Michigan** (35); March 3; four specimens taken March 10; smelt abundant; caught with hook and line; (8, 57, 90, 104) 4 S. **Tobermory, Ontario** (36); December; first record for Georgian Bay; two specimens received by Game and Fisheries Department, Toronto, Canada, and taken from bait gill nets in eight fathoms; (13, 25) 2 S.

LAKE ONTARIO BASIN.—Bowmanville, Ontario; September 9; specimen taken two miles off port in commercial nets and preserved (?) in Royal Ontario Museum of Zoology, Toronto, Canada; several taken in summer 1932 and one seen by MacKay September 10, 1934; "Introduced into Lake Ontario, but apparently with little success" (93); (27, 44) 1 S.

RECORDS FOR 1932

LAKE MICHIGAN BASIN.—Grand Rapids, Michigan; April 30; in Grand River; reported taken in 1931, 1932, 1933, but not verified; most probably not true, although Creaser was inclined to accept the reports as true; (1, 13, 30) **R. Newaygo, Michigan** (37); April; specimens taken at dam on Muskegon River; must have been present therefore in Lake Michigan off Muskegon; (1, 13, 68) R. **Portage Lake, Manistee County, Michigan** (38); winter, a few caught in winter; also taken in 1936; (71, 86) R. **Manistee, Michigan** (39); April; a few taken offshore in commercial trout nets; in fall 1935 taken from piers with hook and line and in spring 1936 in commercial nets; (71, 86) R. **Cut River, Mackinac County, Michigan** (40); April; first run; produced 5,000 lbs. in 1936; (70, 85) R. **Manistique River, Schoolcraft County, Michigan** (41); April; a few seen at mouth; (66) R. **Green Bay tributaries, Michigan**; March–April; first runs occurred in Fishdam, Sturgeon, Day and Ogontz Rivers, Delta County, Michigan, and in Cedar and Menominee Rivers (smelt were reported seen in these two rivers in small numbers for several years earlier), Turtle and Beattie Creeks (only a few smelt in each), Menominee County, Michigan; (65, 69) R.

LAKE HURON BASIN.—North Channel, Ontario (42, 43); April 8; Algoma Creek and Shepherd Creek; first runs on the north shore of Lake Huron; large quantities captured; (94) R. **Port Huron, Michigan** (44); April; two bushels of smelt taken in herring nets; (13, 72) R. **St. Clair River, Saint Clair County, Michigan** (45); April; a few taken (72) R. **Lake St. Clair, Michigan** (46); April ?; a number of smelt runs occurred in the canals around the Flats in 1936; (21) R.

RECORDS FOR 1933

LAKE MICHIGAN BASIN.—Suamico River, Oconto County, Wisconsin (47); spring; first run; (40, 92) R. **Dyckesville, Wisconsin** (48); spring; first run in several streams near Dyckesville; (40) R. **Two Rivers, Wisconsin** (49); May; specimens seen by Schneberger and taken eight miles east of port in twenty-five fathoms; (109) R.

LAKE HURON BASIN.—North Channel tributaries, Ontario (50-57); April 16-May 12; first runs in McBeth Creek at Nesterville, Thessalon River, Livingston Creek, Slip at Blind River, Mississaugi River, Lauzon Creek, Serpent River at Spragge, Stoby Creek at Portlock; (26, 94) R. **Clear Lake, Ogemaw County,**

Michigan; March 30; 500 Boyne City smelt introduced averaging eight inches; no report on results; (73).

RECORDS FOR 1934

LAKE MICHIGAN BASIN.—Milwaukee, Wisconsin (58); specimen plotted on Greene's map; may have been collected earlier; (33) S. Oconto River, Oconto County, Wisconsin (59); March; heavy runs under ice; (42) R.

LAKE HURON BASIN.—St. Joseph's Island, Ontario (60); spring; first runs in several small streams; (94) R. Tawas River, Iosco County, Michigan (61); spring; first run; year uncertain; good runs in 1935 and 1936; (2, 3, 23, 86) R. Saginaw, Michigan (62); April 12; in Saginaw River; (74) 1 S.

LAKE SUPERIOR BASIN.—Marquette, Michigan (63); November 9; specimen taken in commercial nets in Iron Bay and received and identified by Conservation Department, Lansing; (46, 75) 1 S.

RECORDS FOR 1935

LAKE MICHIGAN BASIN.—Pentwater, Michigan (64); November 4; thirty-three pounds taken in 2 11/16-inch mesh gill nets two miles W x S in fourteen fathoms; (45) R.

LAKE HURON BASIN.—Drummond Island, Michigan (65); April 10-25; first runs in Pigeon Cove Creek and a small nameless stream one-half mile E of Drummond; smelt taken by Conservation Department officials; (19, 20, 32, 82) R. Hog River, Simcoe County, Ontario (66); spring; first run in a Georgian Bay tributary; specimen seen by Harkness in spring of 1936; (35) R. Pointe au Baril, Ontario (67); July 15; in Georgian Bay; specimen sent to Game and Fisheries Department, Toronto, Canada; (27) 1 S. Black River, Alcona County, Michigan (68); spring; runs occurred also in 1936; (3, 86) R. Van Ettan Creek, Iosco County, Michigan (69); spring; runs occurred also in 1936; (3,86) R. Au Gres River, Arenac County, Michigan (70); spring; first run; (3, 78) R.

LAKE ERIE BASIN.—Port Dover, Ontario; first record for Lake Erie; rare; (106) R.

RECORDS FOR 1936

LAKE MICHIGAN BASIN.—St. Joseph, Michigan (71); July; taken on hook and line at piers; (6) R. Allegan, Michigan (72); April; small first run, about fifteen to twenty a day, below Allegan Dam on Kalamazoo River; specimen received and identified by Michigan Department of Conservation, April 1; specimens must have been present also off Saugatuck, Michigan; (18, 47, 79, 80) 1 S. Walloon Lake, Charlevoix County, Michigan (73); spring; about fourteen bushels of smelt taken from South Arm Creek, a tributary; probably migrated through Bear Creek from Petoskey; (83) R. Big and Little Sucker Creeks, Emmet County, Michigan (74); April; first runs; (32) R. Crow River, Mackinac County, Michigan (75); April; first run; produced 1,000 pounds; (81, 85) R. Mackinac County streams, Lake Michigan (76-80); spring; production in pounds—Mille Coquins River, 50,000; Rock River, 25,000; Davenport Creek, 25,000; Paquins Creek, 10,000; Black River, 30,000; (85) R. Sheboygan, Wisconsin (81); April; gill nets took several smelt considerably over one-half pound each; (103) R. Waukegan, Illinois (82); April; a few smelt taken in perch and herring gill nets in 8-15 fathoms; about fifty pounds taken from Lake Michigan this spring; Smith (103) informed me that smelt were taken here "several years ago"; (95, 96, 102) R.

LAKE HURON BASIN.—Cape Croker, Ontario (83); March 20; Georgian Bay; specimen sent to Game and Fisheries Department, Toronto, Ontario; (27) 1 S. Carp Creek and Ocqueoc River, Presque Isle County, Michigan (84); spring;

first runs from Hammond Bay; (86) R. **Mill Pond Stream, Alcoma County, Michigan** (85); spring; first run; (86) R.

LAKE SUPERIOR BASIN.—Tributaries east end Lake Superior; spring; runs reported by fishermen (22) but Conservation Department discovered no runs between the Soo and Vermilion, Michigan; (84) R. **Munising, Michigan**; unauthenticated reports received by Conservation Department, Lansing; (86) R. **Keweenaw Bay, Baraga County, Michigan** (86); February; specimen taken in herring net off Aura; the most western record in Lake Superior; also reported in Bay by commercial fishermen of Baraga and L'Anse; (4, 17, 46, 76, 77) R.

LAKE ERIE BASIN.—Vermilion, Ohio (87); June 30; first specimens received from Lake Erie; taken in commercial gill nets sixteen miles NNE in about ten fathoms of water; smelt first occurred in gill nets here about June 20; about fifty were taken by Vermilion gill netters; two specimens taken off Monroe, Michigan, and reported as smelt (111) were identified by me as herring; reports of smelt at Sandusky, Ohio, (21, 22) could not be confirmed; (91, 106) 2 S. **Ashtabula, Ohio**; November; specimens taken in gill nets by Captain George Leidheiser; (106) R. **Port Dover, Ontario**; November; common; during summer each boat took from one to six smelt daily in 4 ¾-inch mesh whitefish gill nets; smelt averaged eight to ten inches in length and two to four ounces in weight; (106) R.

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Discussion

Mr. F. N. Graass (Wisconsin): May I ask Dr. Deason whether he considers the smelt a liability or an asset, and if it is a liability, what is the way to go at it?

Dr. Deason: I hesitate to answer that question. I will say the smelt is an asset in that we have evidence from examinations of stomachs that the lake trout of

Lake Michigan is feeding on the smelt. As to how it is a detriment I would not care to say.

DR. HUNTSMAN: What are the prospects of developing a big fishery for smelt? Are there any figures as to the production in particular areas?

DR. VAN OOSTEN: Last year Michigan produced approximately four million pounds of smelt. In Wisconsin waters the production was probably just as great.

DR. HUNTSMAN: It would probably replace some fish with similar food habits. Would that be the cisco?

DR. VAN OOSTEN: No, it would be the whitefish group.

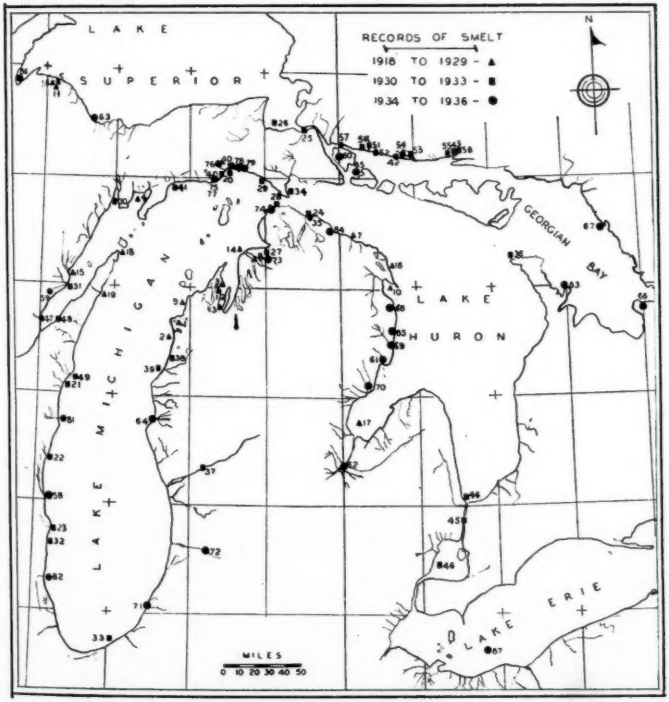
DR. HUNTSMAN: You have no indication of its effect on the fish that take similar food?

DR. VAN OOSTEN: I believe not.

DR. HUNTSMAN: It is almost inevitable that if you have a large production of smelt there will be an effect upon the amount of food produced for other fishes.

MR. GRAASS: It is true that the smelt has a value; I know in my district it amounts to $100,000 in a couple of weeks—that is only in the spring. The rest of the year they are a liability. Their only value is in the spring of the year when the water and the air are cold and they can be shipped.

DR. HUNTSMAN: Usually the smelt is developed as a winter fishery. On the Atlantic coast the smelt is a very great asset; it actually brings in more money in certain districts than any other fish. They are caught in the winter through the ice with bag nets, as they are called, which operate with the tidal water currents. That would not be possible here, but they are also caught in other places through the ice with hook and line and with gill nets, so that there are several methods of catching them through the ice in the winter time.



Map Showing Dispersal of Smelt in the Great Lakes Region

THE SPREAD OF THE SEA LAMPREY THROUGH THE GREAT LAKES.

CARL L. HUBBS

Division of Fishes, Museum of Zoology, University of Michigan, Ann Arbor, Michigan

and

T. E. B. POPE

Milwaukee Public Museum, Wisconsin

In the Great Lakes the sea lamprey *(Petromyzon marinus)* has been known, until recently, only from Lake Ontario and tributary waters below Niagara Falls. As a considerably dwarfed form, the species occurs naturally and abundantly in that lake, and in the Finger Lakes of New York (Gage, 1893 and 1928; Surface, 1898 and 1899; Huntsman, 1917; Dymond, Hart and Pritchard, 1929).

These authors have stressed the predatory destructiveness of the sea lamprey in Cayuga Lake and Lake Ontario. This eel-like creature, averaging about fifteen inches long, when mature, clings to the larger food fishes with a round sucker-mouth, beset with rows of strong, horney teeth; then rasps open a hole in the skin of its victim by means of its serrated tongue plates, and injects an anticoagulating substance into the wound, to insure the free flow of the victim's blood, with which the parasite gorges itself. A considerable proportion of the lake trout, northern pike, bullheads, carp and other fishes in Lake Ontario and the Finger Lakes are reported to bear lamprey scars. The blood-sucking attacks no doubt have a harmful affect on the host fish, and victims of heavy lamprey attacks are occasionally found dead. In Lake Ontario the lampreys even torment swimmers, though there seem to be no records to indicate that they have injured a human being.

The fish of Lake Erie, Huron, Michigan and Superior until very recently seem to have been spared from the attacks of this vertebrate parasite, though they have been less seriously attacked by two smaller native species, of the genus *Ichthyomyzon*.[1] This freedom from attacks by the sea lamprey may to a small degree have been responsible for the large production of fish in these waters, particularly in Lake Erie.

The failure of the landlocked sea lamprey to ascend Great Lakes waters above Lake Ontario has doubtless been the insurmountable obstacle of Niagara Falls (Huggs and Brown, 1929:3). Though lampreys can make their way over steep falls, clinging to the rock walls with their sucking mouths, the Niagara escarpment has presented an im-

[1] Bensley's 1915 hearsay report of Petromyzon marinus from Georgian Bay we now believe was based on a native lamprey (Ichthyomyzon).

passably high barrier. Man-made canals, however, now afford a means by which the sea lamprey and other Lake Ontario fishes can by-pass the great falls. Hubbs and Brown (1929: '17) wrote:

> "The occurrence of the sea lamprey in Lake Erie is a recent discovery. The specimens collected at Merlin, November 8, 1921, were the first for the lake to be scientifically reported (Dymond, 1922, p. 60). Dr. John Van Oosten in the fall of 1927 saw one which had been caught near Sandusky and W. M. Tidd collected one there in the spring of 1928. At the same place Prof. E. L. Moseley saw another about two weeks before Mr. W. D. Bates sent us the specimen from near Rondeau.[2] Mr. Bates told Dr. Van Oosten that he occasionally takes the large lamprey in his nets.
>
> "There can be little question as to the recentness of the establishment of the species in Lake Erie. That it immigrated into Lake Erie from Lake Ontario through Welland Canal is extremely probable. Since the species is much larger than the native lamprey of Lake Erie, *Ichthyomyzon concolor*, and is known to be very destructive to food fishes in Cayuga Lake, New York, and elsewhere, its establishment in Lake Erie adds another potential factor to those responsible for the depletion of the great fisheries of this important lake."

Osburn, Wickliff and Trautman (1930) reported the early taking of another sea lamprey in Lake Erie, one caught near West Sister Island, Ohio, on November 14, 1927.

The first definite indication of spawning runs by the sea lamprey of Lake Erie was furnished by Creaser (1932: 157), who wrote:

> "This lamprey has now penetrated the waters of Lake Erie to one of its western tributaries in the State of Michigan, the Huron River, where an adult specimen was collected at Flat Rock on May 8, 1932. This constitutes a new record for the state (the specimen has been examined), and is an indication of the complete establishment of this lamprey in Lake Erie. The way is now open for a further penetration into Lake St. Clair and Lake Huron. In the not too distant future, it will no doubt be encountered throughout the Great Lakes waters. Knowing its record of destruction among the food fishes of Cayuga Lake in New York, we must consider it as one more source of further depletion of the fisheries of the Great Lakes. The sea lamprey and the smelt *(Osmerus mordax)*, which has recently spread over a great portion of Lake Huron and Lake Michigan, will act as great disturbers of the natural balance of the large fisheries of these extremely productive lakes, which are already in much distress."

More recently, mature sea lampreys have been taken by the Campbell brothers in Swan Creek, a tributary of the Maumee River in Toledo, Ohio, among mature native lampreys. One 455 mm. long, was collected May 8, 1934, and two others, respectively 459 and 528 mm. long, on April 26, 1935. No doubt the species is reproducing in some numbers in the streams tributary to Lake Erie.

By 1930, the sea lamprey had considerably increased in western Lake Erie, and had already made its way beyond that lake. In the second week of May of that year Mr. Melbourn Heubner of Detroit, while fishing in the St. Clair River, caught a sea lamprey, recognizable

[2] This specimen, taken at Pointe Aux Pins opposite Rondeau Harbor, Ontario, was 560 mm. (twenty-two inches) long, larger than any recorded from Lake Ontario.

as such from a colored sketch which he made. This lamprey, thirteen and three-fourths inches long, was attached to the side of a four and one-half pound pike-perch.

Until this year (1936) no further extension of the range of the sea lamprey into the Great Lakes came to our attention, but the pest was undoubtedly dispersing through Lakes Huron and Michigan, probably even breeding in small numbers in creeks tributary to these lakes.

As indicated in Wisconsin and Michigan newspapers, and *The Fisherman* for June, 1936, Capt. Frank C. Paczocha of Milwaukee brought to the Milwaukee Public Museum on March 23, 1936, a sea lamprey sixteen inches long, which he had taken the previous day while fishing in Lake Michigan about fifteen miles east of the city. It was attached to a four and one-half pound lake trout, just below the eye of the fish. Though this fisherman had frequently seen other lampreys on fishes, they were usually much smaller, and presumably of the native species.

The establishment of the sea lamprey in Lake Michigan was confirmed soon afterward, for a male apparently on its spawning run was captured at Elk Rapids, Michigan, on the afternoon of June 13, 1936. This specimen, fifteen and one-half inches long when fresh, was taken by R. B. Zupin, who turned it over to Conservation Officer Mark Craw, who in turn presented it, with appropriate information, to the University of Michigan. Mr. Craw stated that the creature must have come in from the East Arm of Grand Traverse Bay, and that it was found working its way against a swift current in the outlet of Elk Lake, in the spillway behind the Michigan Public Service Company's plant.

The sea lamprey is no doubt not only spreading but also increasing in numbers in the Great Lakes. There is good reason to expec that it will follow the history of the smelt, eventually reaching to the limits of the Great Lakes and greatly increasing in numbers. The multiplication of the lamprey has been at a slower rate than that of the smelt, and will continue so, because the life cycle is much longer: Gage (1928) estimates the larval life of *Petromyzon* as four or five years, and the immature period of adult life as one and one-third to three and one-third years; the smelt spawns when only 2 years old. On account of its slow turn-over, the lamprey will not likely increase alarmingly for several years. In time, however, the sea lamprey may well attain an abundance equal to or greater than that maintained in Lake Ontario and in Cayuga Lake. If that not improbable end be reached, this large and destructive blood-sucking parasite will justify the fears expressed by Hubbs and Brown and by Creaser, quoted above, that it will add one more very serious factor to those already seriously depleting the supply of lake trout, whitefish, suckers, catfish and other commercial fishes in the Great Lakes.

It is doubtful that any attempt to curtail the increase of sea lampreys would prove practicable. At great effort the increase might be retarded, though probably not prevented. As the species becomes abundant enough

to produce definite spawning runs, however, definite control measures may become more effective. The New York investigators, Surface and Gage, point to the spawning run as the most vulnerable period in the sea lamprey's life cycle, for large numbers may then be caught as they move upstream into creeks, or as they build their nests and spawn.

For the present, attempts to control this unwanted and destructive immigrant into Great Lakes waters would seem practically limited to the killing of all individuals caught by fishermen.

To help in further tracing the spread and increase of the sea lamprey in the Great Lakes, specimens caught should be reported, with data as to place and date of capture, and with a statement of the size, color and shape of the fins. The landlocked sea lampreys when adults are usually thirteen to twenty-two inches long, averaging about fifteen inches, while the native lampreys of the Great Lakes other than Lake Ontario almost never exceed thirteen inches and probably never reach fifteen inches in length; the sea lampreys are strongly mottled with dark and light colors, while the native lampreys are almost or quite uniform in coloration; the dorsal fins of the sea lamprey are separated from one another, rather than joined together to form a single fin, and the dorsal and caudal fins are angular rather than rounded, as they are in the native forms. Although these characters will serve to distinguish the sea lamprey from the species naturally occurring in the Great Lakes, it would be helpful and more definite to have specimens sent in for identification. If possible they should be preserved (preferably in formalin, one part to ten of water). A watch should be maintained for spawning runs, which when found should be made known. All such information and specimens may be sent to the University of Michigan Museum at Ann Arbor, to the Milwaukee Public Museum, or to the appropriate state or provincial department of conservation.

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Discussion

Dr. Leonard P. Schultz (Washington): Lampreys are of some value in that the larvae can be dug from the mud in the streams and used as bait. In the state of Washington a man I knew took several thousand lampreys and sold them as bait for bass and other fish, and told me he made about $3,000 that year. On the other hand, once in a while these lampreys are eaten by other fishes; we have found several of the marine fish with lampreys in their stomachs. I do not know whether that occurs in the Great Lakes or not.

EXPERIMENTAL EVIDENCE ON THE VALUE OF TROUT STREAM IMPROVEMENT IN MICHIGAN

CLARENCE M. TARZWELL

U. S. Forest Service, Albuquerque, New Mexico

INTRODUCTION

Although much stream improvement work has been accomplished and numerous papers have been written dealing with the methods of improvement, the evaluation of the results obtained has received little attention. Little or no experimental work has been done with the exception of that carried on in Michigan by the Institute for Fisheries Research. It is believed that more consideration should be given to a study of the permanence and utility of the various types of structures used for improvement work and to the physical and biological changes which they produce in a stream.

While engaged, since the summer of 1930, in the development of methods for the improvement of trout streams, the writer has endeavored to appraise each device and to evaluate its effect on environmental conditions. Many structures were installed primarily for experimental research. The rechecking and evaluation of the various types of stream improvement devices formed the principal part of the investigations carried on in 1931.

OBJECTIVES AND METHODS

Three main objectives sought in testing and evaluating stream improvement devices were:

1. The determination of the most permanent, economical, and effective structures for different types of streams and different situations.
2. The ascertainment of the physical and biological changes produced by each type of stream improvement device.
3. The evaluation of the physical and biological changes produced.

In order to obtain basic data for repeated checking, it was deemed necessary to record the stream conditions before improvement and to take complete notes on the structures which were built. Special forms were devised for these notes. Each structure was marked with a numbered, non-corrosive metal tag and located by its distance from other structures. The size and kind of materials used in each structure were recorded. The extent of the bottom types, such as sand, gravel, rubble, muck, and plant beds, were noted as well as soundings of depth across the stream at one yard intervals, and the number, size, and depth of the pools. Since it was known that some types of bottom are more productive of fish food than other types, the area of different

bottom types in the region of each installation was especially noted. These records, taken when possible at different seasons over a period of several years, made it possible to determine the extent of the physical and biological changes produced by the structures, the importance of these changes from the standpoint of trout production, and the efficiency of the structures.

Several methods were used to evaluate the physical and biological changes produced by the devices. Quantitative studies of the fish food organisms on various types of bottom were made so that the relative productivity of each could be determined. Counts of the organisms were also taken at the sites of the barriers both before and some time after installation. In addition to the counts of organisms, quantitative analyses of the fish population were made in certain sections of stream before and after improvement. Creel census records were kept for the East Branch of the Black River before and after improvement to determine changes in fishing returns.

Effectiveness and Permanency of Stream Improvement Devices

Notes have been taken and rechecks made at all seasons of the year on a total of 2,235 barriers located in eighteen different Michigan streams. In addition, observations have been made on structures in the mountain streams of several western states as well as on the construction done by the Michigan Emergency Conservation Workers. The numerous examinations have supplied data bearing on the stability, utility and comparative cost of the different types of barriers.

As a result of these studies, certain conclusions have been reached concerning the effectiveness and desirability of the various types of devices which have been used, and the materials from which they have been built. Oak and tamarack have proven most suitable for stakes. Sound timber, dead or fire-killed, is most desirable. Pine logs or "deadheads" have proven best for log deflectors, whereas cedar has been found most satisfactory for covers. Tree covers, slanting log covers, the various kinds of submerged bank covers, underpass deflectors and various sorts of wing deflectors made of logs or boulders have proven to be the most satisfactory types of stream improvement devices under most stream conditions. Underpass deflectors have been particularly effective in forming pools. The simple log dam with end cribs and the board dam were found to be the most successful kinds of dams.

The type of stream, it has been learned, determines the sort of improvement devices which should be used. For example, stone deflectors are undermined and quickly rendered useless in sand-bottomed streams; however, where the bottom is firm and large stones are available stone deflectors are preferable. Streams which flood severely require special structures and more bank protection than streams which are not subject to high water. When dams are placed over soft bottoms, such as

are found in many Michigan streams, great care must be taken to prevent undercutting. In this State, dams often cause deposits of barren sand that cover large areas of productive gravel, and destroy the pools. In some streams, "Y," "A" and "I" deflectors can be used to advantage.* Large boom covers and raft covers have been found unsatisfactory on most streams. Rectangular bank covers held by stakes, square covers in the center of the stream, tepee covers and wedge covers, when placed at the surface of the water, are unsatisfactory in streams subject to heavy ice. In such streams all cover devices should be so placed that they will be submerged at the winter levels of the water. Center covers have not been found satisfactory in streams which are subjected to either severe floods or ice action. Although center covers are usually most effective when totally submerged, submerged covers held down with boulders have shown a tendency to become filled underneath in streams which carry large amounts of sand.

Wing deflectors have proved most effective in creating mucky areas, encouraging plant beds, uncovering gravel when it is covered with sand, and in producing gravel and rubble riffles. One of the chief functions of deflectors is to create bottom types which are more productive of fish food. Deflectors built with extremely long directors produce large, thin, mucky areas which are not stable and which produce less food than the original bottom. Wing deflectors, wing jams, slanting logs and trees, and bend covers have been found effective in preventing bank erosion. Brush placed below deflectors is very helpful in building bars which decrease the width of the stream.

With the exception of the structures built the first year (1930) in the Little Manistee River in Michigan, only a few have been lost. Since the work on the Little Manistee River was the first to be undertaken many errors were made and about 30% of the structures installed were lost in five years. During the past five years the loss of structures in the other streams under observation has been as follows: East Branch of the Black River, 2.8%; Gamble Creek, 1%; Pigeon River, 10.6% West Branch of the Sturgeon River, 2%; Salmon Trout River, 4.7% and Black River, no loss. Stumps and raft covers composed a large percentage of the loss. The relatively large loss in the Pigeon River was due to the heavy ice action.

Evaluation of Biological Changes Produced by the Improvement Devices

The change produced by the various improvement structures in the physical and biological conditions of the stream, as related to game fish production, is considered to be a measure of the effectiveness of the devices. Deflectors have proven most successful in producing changes

* The various stream improvement devices have been described by Hubbs, Greeley and Tarzwell, 1932, "Methods for the Improvement of Michigan Trout Streams," Bulletin, Institute for Fisheries Research, No. 1, pp. 1-54, Ann Arbor, Mich.

TABLE 1. SUMMARY OF PHYSICAL CHANGES PRODUCED BY THE INTRODUCTION OF DEFLECTORS IN SIX MICHIGAN STREAMS

Item	Little Manistee River	East Branch, Black River	Gamble Creek	Pigeon River	West Branch, Sturgeon River	Black River
Average increase in av. depth of improved sections, inches	4.1	6.1	3.4	6.7	6.2	1 to 6*
Average increase in pool depth, inches	13.5	10.7	12.2	17.1	12.6	2 to 25*
New pools, number	280	128	76	120	99	17
Increase in pool area, square feet	5,309	13,744	....	....	....	....
Total amount of gravel area uncovered, square feet	37,265	10,340	6,454	26,010	600	....
Av. amt. of gravel area exposed by each deflector, sq. ft.	266	144	122	542	18	....
Total amount of riffle area produced, square feet	40,690	72,372	3,500	21,700	21,600	4,400
Av. amt. of riffle area exposed by each deflector sq. ft.	290	965	66	452	654	734
Total mucky area produced, square feet	21,650	29,445	4,565	14,640	8,695	6,640
Av. amt. of mucky area produced by each deflector, sq. ft.	154	392	86	305	263	1,100
Total area of plant beds produced, square feet	10,980	6,125	8,351	5,730	72,848	1,225
Av. amt. plant bed area produced by each deflector sq. ft.	78	82	158	119	357†	193

* The range rather than the average value is given because of the small number of measurements made.
† This is the average for the total number of devices, not for the deflectors only.

in the type of bottom found in Michigan streams. Since pools and shelter are essential for the production of a large number of adult trout, the success in creating good pools, the deepening and enlarging of existing pools, and the establishment of permanent and effective shelter serves as an important measure of the value of stream improvement.

The physical changes produced by stream improvement in six streams of Michigan are summarized in Table 1. Only the changes produced by deflectors are recorded in this table since nearly all the physical changes resulted from the use of these devices. Very often the original depth was increased several times. Deflectors were more successful in some streams than in others. In the East Branch of the Black River, each deflector produced on the average eighty-two square feet of plant bed, 392 square feet of mucky area, 965 square feet of riffle, and uncovered 144 square feet of graveled area. A greater area of plant beds was produced in the West Branch of the Sturgeon River than in any other stream, decrease since the cover devices also caused plant beds to form in this stream. The average production of plant beds in this river was determined therefore by dividing the total production by the total number of all structures installed.

Each deflector produced on the average 2,027 square feet of improved bottom in the Black River and 1,418 square feet in the Pigeon River. Since these new areas were from four to nine times as productive as the original bottoms, it is apparent that deflectors can be used to increase the production of food organisms.

Three methods were used for the evaluation of the biological changes produced by stream improvement: creel census, fish population studies, and quantitative studies of bottom food organisms. Creel census studies were undertaken on both the Pigeon River and the East Branch of the Black River, but only the returns from the East Branch of the Black River were complete enough to be usable (Table 2). The results indicate that the fishing was much improved after the installation of improvement devices, although such factors as natural fluctuation and migration might have been involved. The time available and expense incurred in making accurate fish counts, before and after improvement, limited the number of counts to four, too small a number on which to draw positive conclusions. It is significant, however, that in all tests made more legal trout were taken and the average size of the trout was greater after improvement.

Quantitative food studies made before and after improvement showed definitely that food production is greater on the type of bottom produced by the improvement structures than on the original bottom. The counts indicate clearly that the types of bottom exposed (gravel and rubble) or produced (mucky areas and plant beds) by deflectors are the most productive. The 447 counts made on six different streams of Michigan are summarized in Table 3. The data are a combination of counts made before improvement, after improvement, and in unim-

TABLE 2. SUMMARY OF CREEL CENSUS RETURNS FROM THE EAST BRANCH OF THE BLACK RIVER, MICHIGAN

Item	Before Improvement	After Improvement
Total number of legal trout caught	71	250
Total time fished (hours)	75.75	167.5
Number of legal fish per hour	0.936	1.495
Number of undersized trout per hour	4.74	3.08
Average length of fisherman's day (hours)	1.64	3.44
Average number of legal fish caught per fisherman's day	2	5
Average size of all fish caught (inches)	4.7	8.7
Per cent of failures	19	7
Per cent of undersized trout in total catch	79	68
Per cent of legal trout in total catch	21	32

proved areas. The data show that the sand areas produce the fewest organisms. If sand is given the population rating of 1, the relative productivity of the other bottom types was found to be as follows: marl, 6; fine gravel, 9; sand and silt, 10.5; gravel and sand, 12; sand, silt and debris, 13; gravel and silt, 14; *Chara* and silt, 27; *Potamogeton pectinatus,* 28; rubble, 29; coarse gravel, 32; *Chara,* 35; mucky areas, 35; medium gravel, 36; *Potamogeton filiformis,* 43; gravel and rubble, 53; sand and gravel with plants, 67; muck, sand and plants, 67; moss on fine gravel, 89; moss on coarse gravel, 111; moss on gravel and rubble, 140; *Vallisneria,* 159; *Ranunculus,* 194; Watercress, 301; and *Elodea,* 452. These relative population ratings show clearly how food production in a sand section of a stream may be increased by a deflector which uncovers gravel and which produces mucky areas and plant beds.

TABLE 3. SUMMARY OF THE AVERAGE VOLUME AND NUMBER OF ORGANISMS FOUND PER UNIT AREA ON VARIOUS BOTTOM TYPES IN THE SIX MICHIGAN STREAMS STUDIED, BASED ON 447 BOTTOM SAMPLES

Type of Bottom Sampled		Rubble	Gravel and Rubble	Coarse Gravel	Medium Gravel	Fine Gravel	Moss, Gravel and Rubble	Moss on Medium Gravel	Moss on Fine Gravel	Sand and Gravel with Plants	Gravel and Silt	Gravel and Sand	Sand, Silt and Debris
Number of Samples		16	12	56	57	15	9	1	1	16	5	71	34
†Oligochaeta	Vol.†	0.17	0.02	0.04	0.07	0.04	0.10	.....	.....	0.34	.....	0.03	0.09
(Worms)	No.	4.37	0.25	3.31	3.03	0.50	12.30	.....	.....	34.10	.....	17.38	9.60
Hirudinea	Vol.	trace	.....	0.08	0.20	.....	trace	.....	.....	2.08	.....	0.06	0.21
(Leeches)	No.	0.60	.....	3.67	7.10	.....	0.20	.....	.....	35.25	.....	1.49	0.40
Gastropoda	Vol.	0.02	0.06	0.03	0.05	0.01	0.02	trace	1.20	0.18	.....	0.08	0.02
(Snails)	No.	1.06	1.90	0.86	1.70	0.80	0.90	1.00	12.00	3.94	.....	1.41	1.50
Pelecypoda	Vol.	trace	trace	0.17	0.66	.....	trace	.....	0.80	1.06	.....	0.46	0.05
(Clams)	No.	0.27	0.18	3.76	28.90	.....	0.40	.....	8.00	48.93	.....	2.64	3.40
Amphipoda	Vol.	.....	.....	0.23	0.13	0.11	.....	.....	.....	0.71	.....	trace	0.01
(Scuds)	No.	.....	.....	17.70	27.20	13.90	.....	.....	.....	47.50	.....	0.93	0.20
Decapoda	Vol.	0.78	0.63	0.17	0.66	0.03	2.24	.....	.....	0.29	0.02	0.19	0.27
(Crayfish)	No.	0.19	0.67	0.22	0.20	0.10	0.90	.....	.....	0.19	0.20	0.42	3.10
Neuroptera	Vol.	0.29	0.68	0.07	0.05	0.04	1.70	.....	.....	.....	0.05	0.06	0.05
(Hellgramites)	No.	3.80	8.15	0.88	1.02	0.50	24.60	.....	.....	.....	1.00	0.11	1.50
Ephemeroptera	Vol.	0.26	0.85	0.42	0.32	0.14	1.41	0.10	0.30	0.61	0.28	0.11	0.17
(Mayflies)	No.	43.48	265.60	130.60	117.90	7.20	761.20	10.00	76.00	231.30	8.30	36.20	17.80
Odenata	Vol.	0.78	0.89	0.50	0.45	0.43	1.24	.....	.....	0.15	1.24	0.09	0.12
(Dragonflies)	No.	5.60	8.50	3.44	2.40	2.70	10.00	.....	.....	1.18	8.20	2.65	1.30
Plecoptera	Vol.	0.23	0.23	0.15	0.05	0.03	0.93	1.20	0.10	0.08	0.01	trace	trace
(Stoneflies)	No.	6.58	23.13	4.27	5.03	1.00	47.40	31.00	4.00	3.68	6.00	0.13	0.10
Hemiptera	Vol.	trace	.....	trace	0.02	.....	.....	.....	.....	0.02	.....	0.01	0.01
(True Bugs)	No.	0.14	.....	0.14	2.50	.....	.....	.....	.....	4.75	.....	0.17	4.00
Coleoptera	Vol.	0.02	0.12	0.05	0.05	0.01	0.35	0.05	0.40	0.07	trace	0.01	trace
(Beetles)	No.	11.90	54.32	24.70	27.10	3.50	227.60	20.00	80.00	4.50	0.40	6.52	3.50
Trichoptera	Vol.	0.81	2.04	1.91	0.85	0.19	8.18	0.90	0.04	1.60	0.11	0.56	0.16
(Caddisflies)	No.	138.16	563.50	245.70	116.30	14.40	2991.30	84.00	64.00	92.60	1.00	51.50	28.60
Diptera	Vol.	0.48	1.04	0.42	0.51	0.12	2.02	7.50	8.78	0.86	0.14	0.35	0.31
(Flies)	No.	29.28	293.90	115.04	126.20	8.30	458.60	210.00	484.00	235.80	7.40	67.96	66.60
Acarina	Vol.	.....	trace	trace	.....	.....	.....	.....	.....	.....	.....	trace	0.01
(Water-mites)	No.	.....	1.47	0.94	.....	.....	.....	.....	.....	.....	.....	0.44	6.40
Petromyzonidae	Vol.	.....	.....	trace	.....	.....	.....	4.50	.....	0.69	.....	0.06	0.22
(Lampreys)	No.	.....	.....	0.06	.....	.....	.....	1.00	.....	0.31	.....	0.11	1.00
All	Vol.	3.81	6.56	4.24	4.07	1.15	18.10	14.25	11.62	8.74	1.85	2.07	1.70
organisms	No.	243.40	1221.60	555.20	466.58	52.90	4535.40	357.00	728.00	743.53	33.00	190.03	149.00

*The Horse-hair worm, Gordius, was found in small quantity in the coarse gravel, P. pectinatus, and Chara.
†All volumes in cubic centimeters or fractions thereof.

TABLE 3—(Continued)

Type of Bottom sampled		Sand and Silt	Sand	Chara and Silt	Muck, Sand, and Plants	Elodea Beds	Water-cress	Ranunculus	Vallisneria	Potamogeton pectinatus	Chara	Potamogeton alli-formis	Mucky Flats	Marl
Number of samples		14	14	1	3	1	3	2	2	4	35	40	28	2
*Oligochaeta	Vol.	0.01	.....	0.50	2.80	0.04	0.31	5.90	0.06	0.15	0.50	0.53	0.10	0.15
(Worms)	No.	1.90	.....	2.00	20.90	44.00	198.70	6252.00	222.00	1.00	15.80	403.60	5.70	1.00
Hirudinea	Vol.	0.51	.....	1.90	0.15	0.36	0.07	.....	.....	.....	1.80	0.41	0.42	.....
(Leeches)	No.	2.30	.....	22.00	4.00	4.00	1.33	.....	.....	.....	19.50	6.45	1.70	.....
Gastropoda	Vol.	0.01	trace	0.08	0.43	4.80	11.23	0.90	14.80	0.05	0.13	0.19	0.42	0.01
(Snails)	No.	0.36	0.07	6.00	58.10	152.00	214.70	48.00	744.00	1.25	6.10	6.74	9.37	0.05
Pelecypoda	Vol.	0.05	0.11	0.06	1.15	1.40	3.27	1.00	2.30	0.18	0.27	0.38	0.39	0.01
(Clams)	No.	6.40	0.09	6.00	0.88	120.00	364.00	14.00	544.00	1.00	44.32	18.48	27.30	0.05
Amphipoda	Vol.	.....	0.01	0.52	0.13	.....	2.57	.....	.....	0.15	0.26	0.97	0.34	0.47
(Scuds)	No.	.....	1.20	72.00	0.21	.....	206.70	.....	.....	15.10	111.30	21.74	5.32	31.00
Decapoda	Vol.	.....	.....	0.10	0.49	2.28	.....	3.00	.....	0.49	0.28	0.66	0.01	.....
(Crayfish)	No.	.....	.....	1.00	117.60	8.00	.....	2.00	.....	1.00	1.40	1.42	0.14	.....
Neuroptera	Vol.	0.01	.....	.....	.....	0.40	0.27	0.61	0.20	0.09	0.06	0.05	0.22	.....
(Hellgrammites)	No.	0.29	.....	.....	.....	12.00	10.60	29.00	20.00	1.50	2.00	1.50	0.38	.....
Ephemeroptera	Vol.	0.28	.....	0.07	0.35	18.80	7.07	0.86	0.06	0.82	0.06	0.37	1.73	0.05
(Mayflies)	No.	5.00	.....	7.00	99.80	620.00	244.00	24.00	38.00	17.00	11.74	101.32	31.20	6.50
Odonata	Vol.	0.24	trace	.....	0.03	0.40	0.59	2.25	0.10	0.25	0.06	0.45	0.56	.....
(Dragonflies)	No.	0.78	0.07	.....	0.13	12.00	4.00	8.00	24.00	1.25	4.30	3.25	2.65	.....
Plecoptera	Vol.	0.03	.....	.....	.....	0.44	0.05	0.05	trace	0.02	0.03	0.01	trace	.....
(Stoneflies)	No.	0.64	.....	.....	.....	24.00	1.33	3.00	4.00	0.25	1.90	5.20	1.39	.....
Hemiptera	Vol.	.....	.....	0.30	.....	.....	0.07	0.05	.....	.....	trace	0.15	0.02	.....
(True Bugs)	No.	.....	.....	6.00	.....	.....	4.00	2.00	.....	.....	0.06	27.54	1.14	.....
Coleoptera	Vol.	0.03	.....	0.05	0.01	.....	trace	trace	trace	0.01	0.01	0.02	0.02	0.03
(Beetles)	No.	0.29	.....	4.00	0.75	.....	2.67	9.00	4.00	0.50	0.80	6.34	18.50	11.50
Trichoptera	Vol.	0.03	trace	.....	0.41	1.60	0.59	0.11	1.00	0.03	1.57	0.79	0.20	0.02
(Caddisflies)	No.	0.78	0.14	.....	16.30	40.00	12.00	12.00	4.00	2.75	1.22	78.04	17.70	3.00
Diptera	Vol.	0.11	0.01	.....	1.31	9.20	9.80	1.00	1.10	0.18	0.17	0.61	0.33	0.05
(Flies)	No.	53.70	0.21	.....	368.90	844.00	966.70	329.00	162.00	15.25	68.00	186.70	91.30	16.00
Acarina	Vol.	.....	.....	.....	0.13	.....	.....	trace	.....	.....	.....	trace	trace	.....
(Water-mites)	No.	.....	.....	.....	17.90	.....	.....	8.00	.....	.....	.....	7.32	0.57	.....
Petromyzonidae	Vol.	0.31	.....	.....	0.76	18.28	3.33	8.40	.....	0.75	0.74	0.04	0.29	.....
(Lampreys)	No.	0.71	.....	.....	0.63	16.00	2.67	10.00	.....	0.75	1.10	0.28	2.80	.....
All	Vol.	1.62	0.13	3.58	8.15	58.00	39.22	24.13	19.62	3.17	5.94	5.63	5.05	0.70
organisms	No.	73.15	1.78	126.00	706.10	1896.00	2233.40	6750.00	1766.00	58.60	289.54	875.92	217.16	69.10

A number of counts were made of the quantity of organisms found per unit area in three Michigan streams before and after improvement devices were installed. These samples were taken in the vicinity of the barriers in order to obtain a direct check on the different structures. The counts (Table 4), show that the volume of organisms per unit area was from three to nine times greater after stream improvement than before it.

TABLE 4. SUMMARY OF THE AVERAGE VOLUME AND NUMBER OF ORGANISMS FOUND PER UNIT AREA BEFORE AND AFTER IMPROVEMENT IN THREE MICHIGAN STREAMS

Name of stream		North Branch of Au Sable River		East Branch of Black River		Pigeon River	
Number of samples		24	40	16	27	8	10
Time in relation to improvement		Before	After	Before	After	Before	After
Oligochaeta	Vol.*	0.12	0.42	0.03	0.40	.....	2.68
(Worms)	No.	1.83	43.10	0.56	6.70	.....	2756.80
Hirudinea	Vol.	0.68	1.86	.....	trace	.....	0.12
(Leeches)	No.	5.25	39.50	.....	0.08	.....	6.00
Gastropoda	Vol.	0.05	0.25	0.02	0.09	0.06	0.39
(Snails)	No.	1.50	5.60	0.19	2.70	2.80	35.20
Pelecypoda	Vol.	0.65	3.20	.....	0.20	trace	0.22
(Clams)	No.	17.80	85.70	.....	2.30	0.10	33.40
Amphipoda	Vol.	0.06	0.86	.....	trace	.....	trace
(Scuds)	No.	8.60	120.70	.....	1.80	.....	0.40
Decapoda	Vol.	0.74	0.60	0.04	0.08	1.08	0.60
(Crayfish)	No.	0.33	0.60	0.31	0.44	1.00	0.40
Neuroptera	Vol.	.....	.....	0.14	0.73	trace	0.48
(Hellgrammites)	No.	.....	.....	1.06	13.50	0.10	11.90
Ephemeroptera	Vol.	0.19	1.03	0.05	0.92	0.03	1.39
(Mayflies)	No.	27.50	389.70	3.20	353.40	1.80	175.00
Odonata	Vol.	0.23	0.58	1.24	1.23	0.02	1.08
(Dragonflies)	No.	0.83	1.80	7.00	7.50	0.50	14.00
Plecoptera	Vol.	0.03	0.10	0.10	0.54	.....	0.16
(Stoneflies)	No.	0.67	5.00	1.40	34.60	.....	35.70
Hemiptera	Vol.	0.01	0.19	.....	0.01	.....	0.01
(True Bugs)	No.	1.58	36.10	.....	0.96	.....	0.40
Coleoptera	Vol.	0.01	0.06	trace	0.16	trace	0.17
(Beetles)	No.	2.37	28.10	0.56	114.50	1.90	68.70
Trichoptera	Vol.	0.28	1.99	0.16	2.98	0.06	2.51
(Caddisflies)	No.	18.50	170.50	8.70	967.70	11.00	433.70
Diptera	Vol.	0.12	1.52	0.15	0.98	0.15	2.13
(Flies)	No.	19.70	382.20	7.50	390.30	9.90	427.00
Acarina	Vol.	trace	.....	trace	.....	.....	0.02
(Water-mites)	No.	0.04	.....	0.30	.....	.....	15.40
Petromyzonidae	Vol.	0.04	0.16	.....	0.13	0.08	1.68
(Lampreys)	No.	0.13	0.20	.....	2.50	0.40	2.00
All organisms	Vol.	3.21	12.82	1.93	8.45	1.48	13.64
	No.	106.63	1308.80	30.78	1898.98	29.50	4016.00

*All volumes in cubic centimeters or fractions thereof.

In addition to the studies made in the vicinity of the barriers, investigations were also conducted on the food production in other sections of the East Branch of the Black River before and after improvement. When the improvements were placed in the East Branch of the Black River, two sections of the stream were more intensely improved than the others.

In the first improved section, which was located just below the lower dam and which had a fast current and a gravel and rubble bottom, forty-four deflectors, three dams, and thirteen covers were installed, comprising a total of sixty structures. This section of the stream is 5,634 feet long and has an average width of thirty-six feet, indicating an area of about 202,834 square feet. The barriers in this section produced 9,390 square feet of mucky flats which equalled 4.6% of the total area; 1,165 square feet of plant beds, equivalent to 0.25% of the total area; and 62,550 square feet of riffle which equalled 30.8% of the total area. Thus the improvements modified about 36% of the total area of this section of the stream. Since these modified areas are types of bottom which are rich in fish food, a considerable increase in food production could be expected. The counts of organisms made before and after improvement showed that on the average the mucky areas below the barriers had four times as much food as the original bottom. These same counts also showed that 4.53 times as much food was found in the riffle areas produced by the barriers as was found in these same areas before the installation of the improvements. Since these counts covered all the different bottom types and since the stream bottom in this section was composed of a rather uniform mixture of fine, medium, and coarse gravel and some rubble, the food production in this area before improvement was considered as unity. After improvement the 30.8% of riffle area produced 139.5% of the former total production, while the five per cent comprised of mucky area and plant beds produced 20% of the former total production; the 64.2% of the area which remained unchanged produced, of course, 64.2%. Thus, the total production of organisms in the improved section of the stream was increased to 223.7% of the former total production, and the improvements increased the food organisms in this section 123.7%.

In the second improved section, located below the upper dam, thirty-three structures were installed—twenty-one deflectors and twelve covers. The area of this section covered about 98,838 square feet. Before improvement the bottom in this section of the stream consisted of medium gravel, sand, and muck. The medium gravel covered 17,950 square feet which equalled 18% of the total area, the muck covered 5% of the total area (a maximum estimate) or 4,942 square feet, while the sand covered 77% or 76,046 square feet. The stream improvement devices in this section uncovered 7,740 square feet of gravel or 7.8% of the total area; produced 7,142 square feet of riffle area which equalled 7.2% of the total area; formed 18,455 square feet of mucky area equiva-

lent to 18.5% of the area; and produced 4,582 square feet of plant bed which equalled 4.6% of the total area. Thus, the barriers modified 38.1% of the total area. Using the results of the food determinations, it was calculated that the riffle areas formed by the barriers produced on the average 4.53 times as much food as the same area produced before improvement.

By using the results of the food determinations and the averages of the volume and number of organisms found on each type of bottom in the East Branch of the Black River, it was possible to calculate the food production in this section of the stream before and after improvement (Table 5). These calculations show that the volume of food was increased almost three times.

It is concluded that, since the improvement devices introduced into the Michigan streams studied have been found to be relatively stable and efficient in producing physical and biological changes, and since these changes have been found in test areas to increase the production of fish food organisms and probably of fish, the improvement work on Michigan trout streams has been successful. Nevertheless, additional evaluation studies on stream improvement, especially with reference to the effect on the abundance of fish, are still urgently needed.

TABLE 5. VOLUME OF FOOD PRODUCTION IN A SECTION OF THE EAST BRANCH OF THE BLACK RIVER BEFORE AND AFTER IMPROVEMENT, CALCULATED ON THE BASIS OF DETERMINATIONS OF BOTTOM ORGANISMS IN THE STREAM

Bottom Type	Average production in cubic centimeters on 4 square feet	BEFORE IMPROVEMENT		AFTER IMPROVEMENT	
		Area of each Bottom Type (square feet)	Total calculated production (cubic centimeters)	Area of each Bottom Type (square feet)	Total calculated production (cubic centimeters)
Sand	0.27	76,105	5,137	48,965	3,307
Muck	3.99	4,942	4,942	23,397	23,397
Gravel	2.76	17,791	12,276	14,719	10,156
Gravel Riffle	12.48	.....	.....	7,142	22,283
Plant Beds	5.32	.....	.....	4.585	6,098
Grand Total		98,838	22,355	98,838	65,241

SOME PRINCIPLES OF BIOLOGICAL FISHERIES RESEARCH[1]

LEONARD P. SCHULTZ

School of Fisheries, University of Washington, Seattle, Washington

This is an attempt to summarize some of the principles of biological fisheries research, as applied to both game fish and food fish management in either fresh or marine waters. The fundamentals underlying both marine and freshwater biological fisheries studies are so similar it appears expedient to consider them together. In any investigation the technique must be worked out for each species by each individual or group of investigators.

The principles considered here, logically fall into four parts as follows: (A) The needs which stimulate biological fisheries investigations, (B) the responsibility of the investigation, (C) the administration of, and the organization for making the investigation, and (D) biological fisheries investigations.[2]

A. Biological investigation may be started, because: (1) In popular opinion the species can not withstand the great toll taken each year or withstand the strain of fishing; (2) fishing is not as good as formerly; (3) of the failure of migratory species to appear in localities where formerly they were abundant; (4) in certain commercial fisheries, the catch has declined to such an extent that it is no longer profitable to fish; (5) the perfection of machinery for the exploitation of fish along with increase of intensity of fishing and the increased utilization of fishery products have caused the thoughtful individual to desire the proper use of the fish resources; (6) pollution, dams, irrigation and erosion destroy spawning grounds and change the environment to such an extent that if fish are to be kept as one of the natural resources these conditions must be corrected; (7) a few administrators of game fish and food fish have discovered a need for definite, scientifically accurate information which they can use for the accurate management of the fishery resources.

B. Obviously most fisheries investigations, except the very simplest, can not be carried out by the individual. The financial responsibility and legal aspect of the problem is such that the *burden of the investigation* must fall largely upon federal, state and local governments or

[1] In the preparation of this paper much help has been received from Mr. H. A. Dunlop and Mr. F. H. Bell of the International Fisheries Commission, Seattle. Information and ideas have been obtained from the following publications: Thompson, W. F., 1919, Fish Bull. No. 2, pages 1-27, Fish and Game Comm. Calif.; Thompson, W. F., and Bell, F. H., 1934, Rept. No. 8, Intern. Fish. Comm.; and Higgins, E., 1934, Quart. Review Biol. 9 (3): 275-291.

[2] The term fishery as used throughout this paper includes in a broad sense, the capture (either by sportsmen or commercial fishermen), the equipment, operation, locality, season, legal aspect, as well as the biology of the species of fish exploited.

upon an international commission. Successful investigations, however, have been made by individuals, corporations, endowed institutions, as well as by colleges and universities, usually in cooperation with the government.

C. The success of any fisheries research program depends to a large extent upon the administration of the organization which will direct it. The types of organizations that have been successful are those in the form of a *permanent* commission, international council, or bureau, composed of non-political appointees, who are advised by a council which represents all interested groups, such as the industry, consumers and sportsmen, legislative bodies, and financial groups. The commissions or bureaus which have produced outstanding practical results have formed a division for each type of work, and have appointed for each investigation a thoroughly competent director who is responsible to the commission or bureau. The usual policy is to investigate first the problems of immediate economic value.

During recent years, marine investigations have contributed more in the way of basic scientific principles for the management of the fisheries than have come from freshwater studies. The explanation of this lies, no doubt, (1) in the greater financial support given the marine research, due to the great importance of commercial fisheries, and (2) in the placing of marine investigations on a permanent basis for continuous observations. Probably if the same attention had been given to the game fisheries as it was in the sea fisheries of the North Sea and elsewhere and as much money made available as for even one of the large marine investigations, we would have our freshwater game fisheries under scientific management today.

An important function of the administrative organization is the popularization of the scientific findings in each investigation. This information should be disseminated in public schools, over the radio, in newspapers and magazines, so that fisheries work would be constantly before a public, thereby made more fish conscious.

D. The actual scientific investigation of game or food fish requires men well trained in that particular field. Each investigation may be divided into six subjects: (1) History of the fishery, (2) the life history of the species, (3) statistics of the fishery, (4) criteria for estimating or determining when the stock has been reduced below the point of a continuous maximum yield, which is overfishing or depletion, and (5) causes of fluctuations in the catch as well as in the stock, and (6) the rational use of the fishery resource and its management.

1. The history of most fisheries may be divided into an early and a recent period. Information can be obtained from the literature as well as by interviews with those well informed, and in the case of marine fisheries, from the log books of fishing boats. The recent history should include data on the fishing methods, equipment, marketing, by-products, men and capital employed, relationships with other industries

and catch statistics. During the process of building up a historical background, the life history of the fish involved in the fishery should be studied.

2. The life history of the species should be explored thoroughly because it is the basis of most legislation for the improvement of the stock available for exploitation. The classification and geographical distribution of the species must be determined. Throughout its range the possibilities of various races or stocks must be investigated. The amount or migration and intermingling of the stocks at all stages of their life, and the physical and biological factors that influence distribution and migration should be studied. The age, growth, age at first maturity, fecundity in relation to age and size, migrations and routes of travel, breeding habits, and mortality at various ages are important. The above-mentioned facts, among others, should be known about the life history, so that the species can be managed on a sound biological basis.

Besides life history studies in the freshwater species, the need for winter investigations and the improvement of lakes and streams in areas where there is need for more fishing grounds, is paramount.

3. The two types of statistics needed in the study of a fishery are: (a) catch statistics and (b) biological statistics. The former should be collected for each area possessing a distinct race and for each type of gear operated for a unit of time. The object of catch statistics is to obtain a picture of the true fluctuations in the amount and value of fish landed. The object of biological statistics is to measure the relative abundance or, better, the actual abundance of the stock. This requires that the catch be separated according to species with adequate biological statistics for each form. A measure of relative abundance may be obtained by recording the catch for a unit of effort which requires a standard unit of fishing gear operated for a unit of time for each race within the area inhabited by the species. The unit of effort must discount the changes in efficiency of fishing as well as competition between different types of tackle or fishing gear used for different units of time.

Other methods of measuring relative abundance of the species may be accomplished by continuous marking or tagging experiments to obtain the rate of recovery or mortality in each age group in comparison with the catch statistics. Size and age composition of the catch may also indicate the mortality rate, for if the catch shifts from old fish to those of younger ages the mortality rate is greater and the relative abundance of the stock is decreased. Quantitative samples of the abundance of eggs will indicate the relative abundance of the spawning stock, when considered in relation to fecundity, size, and sex ratio. Prediction of probable abundance of incoming age classes by number of grilse or precocious males appearing in runs of anadromous fishes has been somewhat successful. Biological statistics furnish the means

of estimating the fluctuations in abundance of the stock year to year, and from them it is possible to determine whether depletion has occurred or when the stock has been reduced below the point of a continuous maximum yield. Some of the criteria for estimating depletion may be summarized as follows: (a) A decreasing yield for a unit of effort year after year, (b) changes in the age and size composition of the stock over a period of years, because if the proportion of mature to immature fish present in the catch from year to year declines in numbers coincident with a decrease in yield for a unit of effort, depletion has commenced, (c) recoveries from marking and tagging experiments from year to year will give an estimate of the mortality occurring in the stock, and the fishing mortality can be deduced. Of course the results are influenced by mortality from tagging, natural mortality, lack of fishing in localities to which the fish migrate, failure to return tags or observe marks or clipped fins.

Fluctuations in the catch of any species must be considered separately from fluctuations in the abundance of the stock or the reserve supply remaining on the fishing grounds. The catch may fluctuate not because of depletion but from other causes some of which are: (a) increased efficiency of fishing equipment, (b) exploitation of new fishing grounds, (c) fluctuations in the consumption and utilization of fishery products and by-products, (d) distribution, marketing, surplus and new methods of preparation, (e) economic and social disturbances such as wars, economic depressions, religious customs and strikes, (f) development of competitive fisheries or associated fisheries, (g) introduction of foreign species which may replace the native form that was the basis of the fishery, (h) pollution, (i) dams and irrigation projects, (j) destruction of habitats by erosion, silting, industrialization, and deforestation, (k) legislation restricting the season, the catch and the size limit, or providing bounties or subsidies, or setting aside nursery or other refuges, (l) transplantation, (m) artificial propagation, (n) stream and lake improvement, and a scientifically based stocking policy.

6. Although the problem of obtaining adequate biological data, and adequate catch or creel statistics is somewhat complicated, the application of the results of scientific investigation is as difficult. The problem is to devise measures to aid in the rational use of the species available so that a continuous maximum yield is obtainable. A species that is not utilized fully may be further exploited by: advertising its value and otherwise encouraging its use; by improving the means of refrigeration, storage, marketing and distribution; by improving the methods of fishing and of fishing equipment; and by making the species more available by constructing roads or by providing means for better transportation.

Some of the measures that may increase or maintain the stock are: artificial propagation, lake and stream improvement, closing of areas

to protect the young, restrict the type and amount of gear used, limit the fishing season, and the total catch, provide proper escapement to spawning grounds for migratory species, and encourage the catching of other species which are predators on the more desirable forms. Attempts should be made to educate the sportsmen and commercial fishermen concerning the needs of increasing and maintaining the stock so that a continuous maximum yield will be obtainable.

Some of the measures that may insure a rational or efficient use of the species must be founded on biological statistics, i. e., the determination of the relative abundance of the stock year after year so that a scientific basis may be established in regard to: size and catch limits for each area, closing of areas to protect undersized fish, restricting the amount and type of fishing gear used, restricting the intensity of the fishing so that the mortality rate is decreased, because an intense fishery takes the available fish while they are still small and a lessened intensity allows them to grow to a larger size and spawn more times but it takes them just the same. The ultimate yield will be the same or greater if the increase in weight exceeds natural mortality during the period they are allowed to live. Additional measures are: closed seasons; transplantation of young fish to regions where the rate of growth is greater; allowing or encouraging the greatest catch to be made just preceding a period of high mortality or after a period of rapid growth; encouraging the utilization of fish in such a way as to profit by any superiority of growth over natural mortality, or attempting to catch fish at a size when the maximum amount of weight and/or value is available from a given number of young entering the commercial or legal size. It is sound practice to catch fish as near the period of consumption as possible if the gain from growth exceeds the drain of natural mortality, and when the fish are in the best condition.

We conclude, therefore, that the abundance of the stock should be managed on a scientific basis so that maximum growth and replacement will occur along with the maximum cropping and that a continuous permanent yield, year after year, may be obtained without endangering the future abundance of the stock. To accomplish this end continuous observations must be made in regard to the biology of the species, as well as securing adequate statistics.

RAINBOW TROUT AND BOTTOM FAUNA PRODUCTION IN ONE MILE OF STREAM[1]

EUGENE W. SURBER

U. S. Bureau of Fisheries Experimental Station, Leetown, W. Va.

The purpose of this paper is to add to the meager data available on the actual production of natural food and fish flesh in trout streams. The first report of the results of one year's observation on production of rainbow trout in Big Spring Creek has already been published (Surber 1933). Since then, accurate data has been kept on the production in this same stream area for the succeeding three years of 1934, 1935, 1936.

The writer believes it worthwhile to call attention to the uniformity of results obtained in a study of the production of natural food during a two year period; the production of fish flesh (rainbow trout); and the kind of food consumed by the fish.

The details of collecting data used during 1934, 1935, and 1936 have been identical with that of 1933. In addition to the data collected during 1933, bottom samples were taken once a month beginning in August 1933 and continuing for a two-year period. A few details of the nature of the stream will be repeated to save the reader's time in referring back to them.

The one mile section of stream includes an actually measured length of 6308 ft. (1.19 miles) along Big Spring Creek near Leesburg, Virginia from the outlet of the head spring to a self-cleaning screen constructed early in the summer of 1932.

The creek flows through open pasture land for about one-half (3,320 ft.) of its length in the experimental section. Except for a few sycamore trees, thorn, and haw bushes, 52.6 per cent of its length is exposed. The remaining 47.4 per cent is shaded to a large extent by sycamore and elm trees, thorn, and haw bushes. The banks of the creek rise two to six feet above the bed. They are steep particularly in the upper half of the section where the stream has cut sharply at the turns producing undercut banks. The source of the stream is a large spring pool with a maximum depth of about three feet. The volume of water leaving the spring has been estimated at between 1,000 and 1,300 gallons flow per minute. Although actual measurements have not been made, the flow appears to be uniform throughout the year. From the head spring to the screen, the creek is a succession of pools and riffles. The aggregate total length of pools was approximately 4,010 feet; of riffles 2,298 feet. The average width of the creek computed from 389 cross measurements was 11.4 feet. The area of sur-

[1] The writer expresses his great appreciation to former Governor Westmoreland Davis, Leesburg, Va., for his aid in making this study possible.

face water, therefore, is roughly 1.65 acres. The nature of the creek bed throughout the section is quite uniform. The riffles, except for about 595 feet, are composed of coarse quartz gravel with stones ranging from about one-fourth of an inch to four and a half inches in diameter. The average-sized stone is about the size of a hen's egg. In the excepted 595 feet of riffles and in 425 feet of pool bottoms are scattered large conglomerate rocks of coarse gravel embedded in a limestone matrix. Water cress, usually thinly scattered along the margins of the riffles and pools, occurs about two-thirds of the distance down the experimental section from the head spring. The bottom of all pools with few exceptions are firm gravel, covered with a thin layer of silt, or firm clay with gravel embedded.

The experimental section has been stocked in late July or August each year with marked fingerling rainbow trout as follows: 1,253 in 1933, 1,080 in 1934, and 2,160 in 1935.

Marking the trout by cutting off such fins as the right and left ventrals has not been uniformly successful as indicated by the results obtained from the fish planted during the fall of 1933 when only nine of the initial 1253 so marked were recaptured. It has been found by subsequent marking that the success in marking is dependent apparently on how carefully this work is performed. This is evidenced by the relatively larger percentage of marked fish recaptured during 1935 and 1936.

The plan of study of the trout production in the creek was as follows:

All pools were numbered and all pools and riffles were measured from the head spring to the screen. The point of capture of each fish was recorded. Each fish was measured from the tip of the snout to the fork of the tail and weighed. These data were used in determining condition factors of the fish and production in pounds per acre of water surface.

Scale samples were removed from each fish for age determinations. During two seasons, stomachs of the captured fish were removed and the items of food identified and counted. Bottom samples were taken after the method of Dr. Paul R. Needham (1927) from August 25, 1933, to February 14, 1934. On February 14, a square foot net, devised at the Leetown Station was used to take the series of bottom samples. The square foot frame consists of two brass frames one foot square hinged together, one of which is provided with a net while the other merely overlies the area of riffle to be sampled. (Fig. 1.)

The net used on February 14, 1934 was 19 mesh OOOOXX bolting silk. The samples on March 9, were also taken with the 19 mesh net. This grade of bolting silk, however, was found unsuited for the work and 23 mesh OOOXXX extra double heavy silk bolting cloth was used on March 13, and succeeding dates.

The device for collecting bottom samples was adopted by agreement by Doctors H. S. Davis, Paul R. Needham, A. S. Hazzard, and the writer at a stream survey conference in Washington, D. C. on January

8, 1934. The mechanical details of the net were worked out at the Leetown station for use by stream survey parties in the National Parks and Forests.

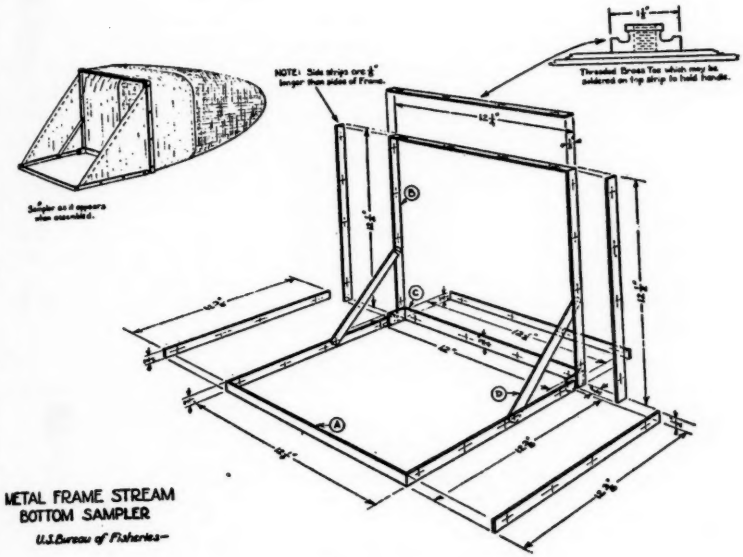
NOTE: Side strips are 8" longer than sides of Frame.
Threaded Brass Tee which may be soldered on top strip to hold handle.
Sampler as it appears when assembled.
METAL FRAME STREAM BOTTOM SAMPLER
U.S. Bureau of Fisheries

FIGURE 1

In this study, bottom samples were collected at seven to twenty-one stations along the mile section. It became possible to increase the number of stations when the new sampler was put into use because of the time saved in manipulation. Bottom sampling and studies of the food of the trout were suspended after two years observations and will not be resumed until condition factors indicate the stream has been overstocked.

Condition factors calculated from length and weight measurements were determined by the following formula:

$$F = \frac{\text{wt.} \times 100{,}000}{(\text{length})^3}$$

The value obtained is a measure of the plumpness of the fish in relation to its length. Our purpose in determining it has been to have a yardstick by means of which we might determine when we have overstocked the stream.

Production of Fish

The results of 1934, 1935, and 1936 are summarized in table 1, and compared with the 1933 results already published.

Attention is called to the following facts illustrated by this table: The actual number and weight of fish removed from the creek each year have been very nearly the same. During the 1936 season, the production of fish was not increased after doubling the stocking intensity. The high flood waters of about middle March may have been a factor in bringing the number of fish captured to the levels of the preceding years. In 1936 after the stocking intensity was doubled, the fish made excellent growth as in previous years, and their condition factors did not reflect any greater competition for food than existed in previous years.

Not as many marked fish were recaptured during 1936 as during 1935, indicating that the job of marking again was not done well. During 1935 and 1936, age determinations from the scales were not relied on in calculating survival of fingerling fish planted the preceding fall because of natural propagation in the stream and the fact that age determinations made thus far have shown that annulii are not formed by all fish each year (See results of age determinations).

TABLE 1. PRODUCTION OF TROUT

	1933	1934	1935	1936
Number of No. 4 fingerlings planted fall of year preceding that shown at head of column	950	1253	1080	2160
Total number of fish captured (Marked and unmarked)	93	132	124	103
Total hours of fishing effort	123	120	80	116
Catch per hour	0.76	1.09	1.54	1.13
Production of fish in lbs. per acre	29.7	27.7	34.8	30.2
Survival from number planted preceding fall (per cent)	8.3*	7.5*	6.0†	1.5†
Average condition factor of all trout taken	43.80	41.99	42.58	42.62
Number of marked fish recaptured (planted preceding fall)	....	9	65	32
Number of marked fish of other plantings recaptured	....	....	2	9
Number of undersized trout killed	5	15	1	3
Number of 8- 9 inch trout captured	9	30	16	25
Number of 9-10 inch trout captured	30	34	43	26
Number of 10-11 inch trout captured	16	27	35	21
Number of 11-12 inch trout captured	13	12	8	13
Number of 12-13 inch trout captured	4	5	17	5
Number of 13-14 inch trout captured	5	5	1	3
Number of 14-15 inch trout captured	1	....	3	4
Number of 15-16 inch trout captured	1	....	....	3
Total number of fish	84‡	126‡	124	103

* Age determinations from scale samples as well as marked fish used in arriving at this figure.

† Calculated from marked fish only.

‡ Length measurements of all fish taken not included. Part of data misplaced.

Results of Age Determinations

During 1934 as in 1933, scale samples were taken from all of the fish caught, but age determinations from the scales were made only on the unmarked fish. An analysis of the scales showed a total of 125 fish with

one annulus or none (II year); five were III year fish; one belonged to the IV year class according to the growth zones; and the remaining fish, a small one fatally hooked, was probably in its first year.

In 1933, thirty per cent of the trout which must have passed their first winter showed no annulus. In 1934, twenty per cent were without definite annulii. This is probably explained by the abundance of food and the relatively uniform water temperature throughout the year. Age determinations as a supplementary means of checking up on the results of annual plants in this section of stream have therefore been abandoned.

Food Studies

The results of a frequency analysis of the food of trout taken during 1934 are summarized in table II.

TABLE 2. SUMMARY OF FOOD STUDIES

Rank	Common Name	Scientific Name	Frequency in 131 Fish
1	Scuds, shrimp	Gammarus	98
2	Mayfly nymphs	Baetis	59
3	May or June Beetles	Scarabidae	56
4	Midge fly larvae	Chironomidae	48
5	Caddis pupae	Trichoptera	46
6	Ants	Formicidae	46
7	Midge pupae	Chironomidae	41
8	Crayfish	Cambarus	35
9	Grasshoppers	Acrididae	31
10	Wasps	Hymenoptera	30
11	Microscopic plants	Algae	28
12	Ground beetles	Carabidae	25
13	Water boatmen	Corixidae	24
14	Snails	Mollusca	23
15	Caddis larvae	Glossosoma IV.	19
15	Misc. and unknown beetles	Coleoptera	19
15	Flies	Diptera	17
16	Click beetles	Elateridae	16
16	Weevils	Rhyachophora	16
17	Crickets	Gryllidae	12
18	Caterpillars	Lepidoptera	9
18	Water striders	Gerridae	9
19	Crane flies	Tipulidae	7
19	Leaf hoppers	Cicadellidae	7
20	Lady beetles	Coccinellidae	6
20	Caddis larvae	Trichoptera	6
20	Hairworms	Gordiacea	6
21	Water Scavenger beetles	Hydrophilidae	5
21	Spiders	Araneae	5
21	Stink bugs	Pentatonidae	5
21	Millipedes	Myriapoda	5
22	Crawling water beetles	Haliplidae	4
22	Caddis flies	Trichoptera	4
22	Riffle beetles	Parnidae	4

A study of the items of food consumed by the trout captured during the 1934 season show a greater dependence on the aquatic organisms present in the stream than during the preceding season (Surber, 1933). Mayfly nymphs, *Baetis,* were much more important. One fish 8.5 inches long had consumed 102 *Baetis* nymphs as well as 78 *Gammarus,* one water bug *Zaitha flumineum,* 4 caddis pupae, 1 crane fly, 2 Hydropsyche larvae, and a midge pupa. A 13.15 inch fish had eaten 848 Gammarus, a water boatman, and a may-beetle. The Gammarus in the stomach of this fish were nearly all intact, and with the two other items made a stomach full, weighing 2.475 grams after being dried in an oven. The greater predominance of aquatic food was undoubtedly due to the absence of destructive freshets. Scuds or fresh water shrimp were present in the stomachs of nearly all fish. Filamentous algae were again an important item of food and were found in 28 of the 132 fish (21.3 per cent) examined.

As was the case in 1933, no definite cannabalistic tendencies were observed. A scale of a sunfish was found in the stomach of one fish.

Although Table 3 indicates that the aquatic animals Gammarus, Baetis nymphs, midge larvae, and caddis pupae were important throughout the fishing period, catches of rainbow trout on different dates reflect seasonal changes in the abundance of winged terrestrial insects. For example, more may beetles were present in the catches of May 30, June 3, and 8, than on May 27 and succeeding dates. Scarabid beetles present in the fall examinations were not of the same species as those eaten in the spring. In July terrestial insects of great variety were eaten. On July 29, and August 7, grasshoppers were prominent. The examinations of stomachs from trout taken on September 24, 1934 showed an abundance of crickets, and winged red ants.

Bottom Fauna

The first series of bottom samples was collected on August 25, 1933, a few days after a severe freshet (August 23) had ground up the coarse gravel in the riffles, swept away most of the bottom animals, and polished the stones which subsequently appeared fresh and barren. Recovery from the freshet was surprisingly rapid, and within six or seven weeks, the bottom animals were becoming abundant. From August 23, 1933 until March 3, 1934, the tranquility of the stream was not disturbed. On the latter date, snow melting rapidly caused a slight rise in the creek. A freshet destructive to bottom animals did not occur until August 11-16, 1934 when heavy showers brought the creek up between 3-4 feet at the screen. Then, this was not particularly destructive in comparison to the freshet of August 23, 1933 resulting from record rains which accompanied the severe tropical storm that swept the Atlantic seaboard at that time. Attention is called to these freshets because they appear far more important than seasons in regulating the abundance of bottom animals in this stream.

TABLE 3. RESULTS OF BOTTOM FAUNA STUDIES
August 25, 1933 to September 9, 1935
Average number of the principal organisms per square foot

Date	Number of samples	Flatworms	Oligochaets	Gammarus	Crayfish	Baetis nymphs	Hydropsyche larvae	Hydropsyche pupae	Glossosoma larvae	Glossosoma pupae	Simulium larvae	Antocha larvae	Parnid larvae	Parnid beetles	Chironomid larvae	Average wet weight (Grams per sq. ft.)	Average dry weight
8/25/33	9	0.6	0.4	29.0	0.7	16.7	5.9	1.0	0.7	0.0	0.1	1.7	6.6	3.3	0.3	0.303	0.056
10/10/33	9	0.6	0.0	121.4	0.3	25.4	36.9	0.0	4.0	0.0	3.3	0.2	58.0	14.4	1.8	1.347	0.253
11/ 8/33	14	7.7	5.2	279.3	0.9	33.5	70.1	1.0	10.5	0.0	1.3	0.5	58.3	17.8	1.8	2.870	0.527
12/ 8/33	13	2.6	2.5	344.7	2.3	15.8	32.5	0.1	6.8	2.2	0.2	0.2	23.8	10.1	1.5	4.025	0.753
1/ 5/34	12	3.0	0.8	252.8	0.4	87.4	51.2	0.0	19.3	5.8	0.4	0.7	26.8	19.5	9.3	3.297	0.647
2/ 8/34	12	3.5	1.4	318.5	0.5	82.9	55.1	0.8	5.0	5.7	0.5	0.6	18.2	12.5	5.2	4.187	0.743
2/14/34	8	0.7	0.0	274.9	0.0	14.5	22.4	0.0	9.2	7.5	0.0	0.3	9.7	7.5	0.2	3.871	0.754
3/ 9/34	14	1.9	1.3	218.5	0.3	35.4	73.4	0.0	14.1	4.0	0.1	0.3	19.9	15.2	3.6	3.533	0.704
3/13/34	10	3.7	0.1	382.5	0.7	32.0	76.6	3.7	29.2	2.1	0.2	0.2	16.2	20.5	2.1	4.689	0.905
4/ 8/34	15	2.0	0.7	606.5	0.8	42.2	54.5	4.3	31.9	4.5	0.0	1.1	15.0	19.4	5.1	7.135	1.141
5/ 8/34	15	3.8	1.5	789.7	0.5	9.5	23.5	6.3	7.1	21.3	4.3	3.5	16.1	13.7	29.9	7.228	1.752
6/ 8/34	17	6.9	3.6	1208.4	0.4	86.1	22.4	5.5	11.1	11.2	1.1	1.1	71.5	19.8	2.0	10.599	2.341
7/ 8/34	16	3.2	0.5	751.4	0.6	57.8	33.1	0.8	11.9	4.0	0.2	0.5	44.8	38.9	4.7	5.690	1.336
8/ 7/34	21	5.1	0.0	932.8	1.3	80.7	70.0	3.7	59.8	10.3	1.3	5.5	43.5	32.6	9.8	9.868	1.642
9/ 9/34	17	4.1	0.0	790.6	1.1	85.3	100.6	8.5	29.7	15.1	0.0	6.0	50.8	35.4	12.1	7.112	1.282
10/ 8/34	12	1.5	0.1	315.8	0.7	29.3	37.3	0.5	1.2	1.5	0.1	0.0	15.5	14.5	13.2	4.143	0.913
11/ 8/34	15	2.1	0.0	530.0	0.4	84.5	54.5	0.3	3.9	1.4	0.3	0.8	26.9	10.7	41.5	6.484	1.468
12/10/34	11	3.4	2.8	266.8	0.3	56.1	44.3	0.1	2.9	1.1	0.7	1.5	16.7	8.4	23.1	4.204	0.852
1/ 8/35	14	2.7	0.3	206.1	0.0	117.3	41.4	0.2	2.9	2.8	0.2	2.0	26.5	6.2	37.3	4.222	0.858
2/ 8/35	14	5.7	1.3	303.1	0.0	110.9	41.3	2.3	1.6	4.0	0.1	6.5	23.8	9.8	35.1	4.573	0.972
3/ 8/35	16	4.1	2.2	314.4	0.3	82.0	25.3	3.8	2.8	1.1	0.3	1.9	14.1	6.9	26.0	5.853	1.152
4/10/35	16	3.8	0.3	418.4	0.8	82.9	23.9	5.1	5.9	6.4	0.7	13.6	23.9	11.3	50.7	9.075	1.632
5/ 8/35	7	2.4	4.4	797.4	0.4	114.3	20.2	2.2	6.9	5.8	0.0	0.8	42.9	8.7	17.7	13.823	2.744
6/ 8/35	15	1.3	0.1	1670.3	0.4	54.1	29.2	2.3	5.1	3.5	0.2	1.1	56.1	14.8	16.1	7.615	1.606
7/ 8/35	15	3.1	1.6	999.3	0.6	73.5	29.2	3.5	19.1	5.9	0.0	7.4	43.2	18.1	34.6	9.817	1.604
8/ 8/35	12	7.0	0.6	1062.3	2.8	66.9	54.6	2.6	7.5	8.6	0.3	4.1	65.8	17.1	16.5	5.739	1.306
9/ 9/35	16	13.6	0.3	714.9	3.1	58.9	47.1	4.1									

The results of a study of bottom samples taken over a two year period in midstream in the gravel riffles are reported in Table III. In addition to obtaining the wet weight of bottom animals, their dry weight was determined by drying the wet-weighed samples in a constant temperature oven at 60 centigrade for at least 24 hours. The average dry weight is about nineteen per cent of the wet weight.

The average wet weight of bottom animals per square foot during the first year was 5.047 grams while the average dry weight was 0.982 grams. Applied to the 2,298 linear feet of riffles in the mile section, an average daily standing crop of 485.8 pounds per acre wet weight, 94.5 pounds per acre dry weight was recorded. The peak of production during 1934 was attained on June 8, at 1,020.2 pounds per acre wet weight and 225.3 pounds per acre dry weight. This 1934 peak was surpassed in 1935 during the same month as shown in Table III. The richness of this stream is demonstrated by comparison with observations by Paul R. Needham (1927, p. 194) and V. S. L. Pate (1932, p. 137). Needham in a comparison of different types of bottom found that coarse gravel was the third most productive type of bottom, yielding on an average 1.281 (wet weight) grams per square foot. Pate found that 54 samples from coarse gravel averaged 1.17 grams per square foot wet. When compared with lake production, it is interesting to note that Juday (1922) determined the weights of the benthic animals of the intermediate and deep water zones of Lake Mendota and found a wet weight production of 320.7 pounds per acre in the 8-20 meter zone and 620.8 pounds in the 20.5-23.5 meter zone (dry weights 42.9, 68.1 lbs. per acre, respectively).

When the bottom fauna studies were continued through a second season, it was found that the results for the second year compared closely with the results of the first season's sampling. The average wet weight of bottom animals during this second year was 6.695 grams as compared to 5.047 grams, while the average dry weight of 1.321 grams of the second year compared with 0.982 of the first year.

The question of the variability of these bottom samples naturally arises. To answer this question, the mean deviation in the number of Gammarus and the dry weights of bottom animals in the samples of May, June, and July 1934 was determined. The mean deviation is the average of all the deviations from the mean or average, regardless of whether or not the deviation is more or less than the mean or average. The mean number of Gammarus in May was 790, the mean deviation 207, per cent of deviation 26.2; the mean number in June was 1208, the mean deviation 360, per cent of deviation 29.8; the mean number in July was 751.4, mean deviation 270, per cent of deviation 35.9. Again, using the dry weights of individual samples, the May mean or average was 1.752 grams, the mean deviation 0.505, the percent of deviation 28.8; in June the average dry weight was 2.341 for 16 samples, the mean deviation 0.552, per cent of deviation 23.6; in July the mean

dry weight was 1.336 grams for 16 samples, the mean deviation 0.515 grams and the per cent of deviation 38.5.

The scud, *Gammarus fasciatus* (or *Dikerogammarus fasciatus*) as it is properly named according to Smith (1933), is the predominating organism in all bottom samples. These animals swim or crawl in the spaces between the stones of the gravel riffles.

The splendid growth made by the trout planted together with the bottom fauna data have demonstrated thus far there has been no scarcity of food.

Summary

Plantings of rainbow trout fingerlings in approximately a mile section of a spring fed creek averaging 11.4 feet in width and comprising about 1.65 acres were followed up to determine their survival and the annual production of fish in pounds per acre. The results of four years' observation showed little variation in the production for the years 1933, 1934, 1935, and 1936 when 29.7, 27.7, 34.8, and 30.2 pounds per acre of trout, respectively, were removed. When the number of fish planted during the fall of 1935 was doubled, the production remained the same, although the flood of middle March, 1936, may have had some effect on the number of fish that survived.

The condition factors of all trout were determined, and this factor, which had not yet varied significantly, still remained at a satisfactory level (42.6) during 1936 after the stocking intensity had been doubled. In all seasons, the majority of these planted fish have made excellent growth, most of them attaining a length of nine inches or more by late May.

Food studies made during 1934 demonstrated the great dependence of the rainbow trout on terrestrial insects during the summer period, but these studies also showed greater dependence on the aquatic forms in the creek than during the previous season of 1933.

Bottom samples were taken monthly for a two year period. When the results for the two years in grams per square foot were compared, they were found surprisingly alike. During the first year beginning in August 1933, the average wet weight of bottom animals was 5.047 grams, dry weight 0.982 grams. The averages for the succeeding year were 6.695 grams wet and 1.321 grams dry weight, respectively.

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MIGRATION, GROWTH RATE, AND POPULATION DENSITY OF BROOK TROUT IN THE NORTH BRANCH OF THE AU SABLE RIVER, MICHIGAN*

DAVID S. SHETTER

Institute for Fisheries Research, Michigan Conservation Department
Ann Arbor, Michigan

Since the trouts, and particularly the brook trout, are among the important fishes pursued by the sport fishermen in the waters of Michigan, any information concerning their habits in natural waters will be a distinct aid in a management program. This paper discusses briefly the information obtained to date from recoveries of tagged wild brook trout marked and recovered in the North Branch of the Au Sable River. Tagging has been carried on since July 1934, and is being followed through at the present time.

These studies have been conducted on the North Branch in the region of Lovells, Michigan, located in the northeastern corner of Crawford County. This particular stream was chosen for the following reasons:

1. It supports a relatively large brook trout and brown trout population. There were formerly many rainbow present but they have dwindled in recent years.
2. It is, through most of its course, a wide and relatively shallow stream and consequently is more readily seined than most trout streams.
3. It is rather heavily fished by an exceptionally intelligent class of fishermen, and it was felt that they would readily cooperate by reporting any captures of tagged trout.

The so-called "strap" or clip type tag, bearing a serial number, was chosen from the three types † available as the tag most suitable. This tag is applied to the mandible of the trout by a relatively simple operation. A small slit is made with a sharp knife or scalpel under and inside the mandible. The short end of the tag is inserted through this slit and is then clamped through the lock-hole on the opposite (long) end of the tag so that the jawbone is completely and firmly encircled when the projecting lockpiece is pinched down with a jeweler's pliers. To allow for growth of the jawbone, the resulting elongated oval is spread to an approximately circular shape by pressure on the tag applied from both ends by means of the pliers. The feasibility of this method of tagging has been demonstrated by hatchery experiments (Shetter, 1935).

* This study has been conducted through the medium of tagging. It has been in operation since July 1934, and still is being followed through at the present time.

† Cobb (1933) conducted an experiment along similar lines in Connecticut trout waters. However, he worked with hatchery fish using the internal tag, and all recoveries were made by fishermen.

The pools or portions of the stream that were seined were selected by cruising the stream carefully to locate comparatively heavy concentrations of fish in water that could be seined. Seines of different mesh size and lengths were tried out, but the most success was obtained by the use of a ⅜" mesh (bar measurement) fifty feet long and six feet deep.

With the exception of a few quiet-water pools, most of the seining had to be done down stream or across the current. Captured fish were placed immediately in a wash tub half full of water, or were measured and tagged directly from the seine. The fish were measured on a board on which a ruler had been inset. Total lengths only were recorded during the first two summers, but since this spring, standard, total and fork measurements have been taken.

Careful notes, both on tagging and on subsequent recovery are kept as follows: date, location, lengths, species, tag number. During this summer (1936), scale samples have been taken from all fish tagged and all fish recovered.

Each recovery is recorded on a separate card, as this was found to be the most convenient method of filing the recoveries (Figure 1). This filing method facilitates compilation of all data.

193..... NORTH BRANCH OF THE AU SABLE

..... Year Experiment

(BROOK), (BROWN), (RAINBOW), ...(.....)

..... Species Tag No.

How Recovered (SEINED), (FISHING) By Whom (I. F. R.)

Date when Recovered..... Length when Recovered.....

Date when Tagged..... Length when Tagged.....

Total Days Out..... Growth in Eighth Inches.....

Stream or Lake County T R Sec. Location

Where Tagged NORTH BRANCH ....

Where Recovered..... ....

Distance traveled.....miles Direction traveled (UP), (DOWN), (NONE)

INSTITUTE FOR FISHERIES RESEARCH
MICHIGAN CONSERVATION DEPARTMENT

TAGGING EXPERIMENTS RECOVERY DATA

Fig. 1—Card used to file information on the recovery of a tagged fish. Size 3 x 5 inches.

Migration—The migration data of this paper are based on recoveries obtained from brook trout tagged between July 25, 1934 and February 15, 1936. Between these dates 3,098 brook trout, 161 brown trout and 6 rainbow trout were tagged. Between the same dates 776 (25%) brook trout, 17 (10.5%) brown trout, and 2 (33%) rainbow trout were re-

covered—a total of 795 trout or 24.3%. A large number of the brook trout have been recovered from one to five times during various seasons; therefore many more records of growth and migration are available than the above figures indicate. These duplicate recoveries should be an added source of detailed information on seasonal growth and movements when the study is completed, since through these recoveries one can trace the life history of individual fish over a period of time.

Recoveries have been assembled into two different groups:—those recovered during the same year that they were tagged, and those that were recovered after they had been free over at least one winter. Tables 1 and 2 give the results of the recoveries within the years 1934 and 1935 respectively. Tables 3 and 4 give the results of over-winter recoveries for the years 1935 and 1936 respectively. The following facts may be determined from the data in these tables:—

1. The brook trout in the region of Lovells do not undertake any extensive movement during the months of June, July, August, and early September. The majority (anywhere from fifty to 100 per cent) show no migration (Tables 1 and 2).

TABLE 1. WILD BROOK TROUT TAGGED AND RECOVERED DURING 1934

Tagged	Recovered						
			Down Stream		No Migration	Up Stream	
Month	Month	No.	%	Av. Miles	%	%	Av. Miles
July	July	42	23	0.45	67	10	1.10
July	Aug.	135	6	0.35	83	11	0.62
July	Sept.	62	21	0.50	60	19	0.50
July	Nov.	48	31	0.40	11	58	0.59
Aug.	Aug.	57	..	....	100	..	....
Aug.	Sept.	60	10	0.60	75	15	0.26
Aug.	Nov.	18	45	0.40	..	55	0.30
Sept.	Sept.	89	4	0.60	91	5	0.10
Sept.	Nov.	84	15	0.19	33	52	0.65
Nov.	Nov.	6	..	....	67	33	0.24

2. Recaptures of tagged brook trout on the spawning beds during late October and early November indicate that the majority (between fifty and fifty-five per cent) of the breeding fish moved upstream on the average of less than a mile (0.785 mi.) to spawn. Approximately twenty per cent of the fish recovered were found to spawn in the immediate vicinity of the tagging locality. Approximately twenty-five per cent of the fish recovered had moved down stream to spawn, traveling on the average slightly less than one-half mile (Table 1 and 2).

3. The direct evidence on the winter migration habits of the brook trout is scanty. Results of winter and early spring seinings in the same areas that ordinarily contain trout throughout the warmer months of

the year are shown in Table 5. The scarcity of fish in the seine hauls certainly indicates that the trout population has deserted this region during the colder months.

TABLE 2. WILD BROOK TROUT TAGGED IN 1935 AND RECOVERED JUNE 1935 THRU JANUARY 1936

Tagged		Recovered					
			Down Stream		No Migration	Up Stream	
Month	Month	No.	%	Av. Miles	%	%	Av. Miles
June	June	10	..	....	90	10	0.12
June	July	2	50	0.25	..	50	1.50
June	Aug.	35	36	0.32	48	16	0.16
June	Sept.	8	13	3.00	50	37	0.12
June	Nov.	33	21	0.75	30	49	1.60
Aug.	Aug.	33	13	0.50	69	18	0.10
Aug.	Sept.	100	4	0.10	92	4	0.35
Aug.	Nov.	82	19	0.44	35	46	0.60
Sept.	Nov.	21	9	0.75	29	62	0.30
Nov.	Nov.	28	29	0.70	64	7	0.20
June	Jan.	6	16	0.12	17	67	0.43
Aug.	Jan.	16	37	0.32	13	50	0.40
Sept.	Jan.	2	50	1.12	..	50	0.06
Nov.	Jan.	52	19	0.31	54	27	0.08

However, from Tables 3 and 4 it will be seen that the majority (fifty-three per cent) of the fish recovered in April and May were taken at points down stream from where they were recorded during the summer and autumn of the previous year. This fact, combined with the results of the winter seinings of 1936, seems to bear out the conclusion that there is a downstream movement of the bulk of the trout population during the colder, winter months. This movement may possibly carry them as far as the Main Stream of the Au Sable (18 miles down stream). One recovery of a tagged fish from a stream on the southern side of the Au Sable drainage suggests the possibility that some, at least, may perform this relatively lengthy migration.

4. It will be noted that at least one-third of the over-the-winter recoveries taken in mid-summer and early fall were fish that had returned to the place where they were tagged the previous year. The remaining two-thirds of the mid-summer and early fall recoveries were, on the average, less than a mile up stream or down stream from the point of tagging, indicating that the bulk of the population returns each year to the same general areas occupied the preceding year (Tables 3 and 4).

Growth Rate—Since certain European writers (Wunder, Debrosses, 1935) have expressed the opinion that tagging on the gill cover of coarse fishes reduces the rate of growth, the effect of jaw tagging on rate of growth of trout was tested in two hatchery experiments. The results of these experiments are shown in Table 6.

TABLE 3. OVER-THE-WINTER RECOVERIES MADE DURING 1935 ARRANGED TO SHOW MIGRATION TRENDS

Tagged Month 1935	Month 1936	Total No.	Recovered								
			Down Stream			No Migration			Up Stream		
			No.	%	Ave. Miles	No.	%		No.	%	Ave. Miles
Sept.	May	1	..	..	....	..	..		1	100	0.50
Nov.	May	2	1	50	0.75	1	50		..	..	....
July	June	6	4	67	1.30	..	..		2	33	1.50
Aug.	June	2	1	50	0.12	..	..		1	50	1.75
Sept.	June	11	5	45	0.80	4	37		2	18	2.00
Nov.	June	8	3	37.5	0.33	3	37.5		2	25	0.50
July	Aug.	5	2	40	1.75	2	40		1	20	0.06
Sept.	Aug.	5	2	40	0.38	1	20		2	40	0.63
Nov.	Aug.	6	1	13	0.25	..	..		5	87	0.87
July	Sept.	2	..	..	....	1	50		1	50	1.625
Sept.	Sept.	2	1	50	0.12	1	50		..	..	....
July	Nov.	2	1	50	0.12	..	..		1	50	0.12
Sept.	Nov.	4	2	50	0.37	2	50		..	..	....
Nov.	Nov.	5	..	..	....	4	80		1	20	1.25

TABLE 4. OVER-THE-WINTER RECOVERIES MADE DURING 1936 (TO JULY 26) ARRANGED TO SHOW MIGRATION TRENDS

Tagged Month 1935	Month 1936	Total No.	Recovered								
			Down Stream			No Migration			Up Stream		
			No.	%	Ave. Miles	No.	%		No.	%	Ave. Miles
June	April	1	1	100	0.5	..	..		..	..	....
Aug.	April	4	2	50	2.0	2	50		..	..	....
Sept.	April	3	3	100	0.2	..	..		..	..	....
Nov.	April	2	..	..	....	1	50		1	50	11.0
June	May	3	2	67	1.0	1	33		..	..	....
July	May	2	..	..	....	1	50		1	50	4.0
Aug.	May	10	4	40	2.8	1	10		5	50	0.4
Sept.	May	6	2	33	*	1	16		3	50	1.1
Nov.	May	9	8	89	1.0	..	..		1	11	3.25
Aug.	June	6	1	16	0.75	2	33		3	50	1.0
Nov.	June	3	2	67	1.75	..	..		1	33	1.0
Aug.	July	10	3	30	0.75	5	50		2	20	0.06
Sept.	July	1	..	..	....	1	100		..	..	....
Nov.	July	17	5	30	0.75	11	63		1	7	1.75

* Mileage not given as one trout moved out of the North Branch.

TABLE 5. ABUNDANCE OF BROOK TROUT IN SEINE HAULS DURING MID-WINTER AND EARLY SPRING, 1936, IN THE NORTH BRANCH OF THE AU SABLE RIVER, MICHIGAN

Month	Number of Hauls[1]	Total Trout Captured	Ave. Number of Trout Per Haul	Remarks
Jan.	11	800-1000	80-100	Close to normal summer size range.
Feb.	12	43	3.0	About 5% legal trout (7 inches).
March	14	11	0.8	All less than 6 inches.
April	15	55	4.0	About 5% legal fish.
May	21	336	16.0	Less than 10% legal fish.

[1] 30 ft. x 6 ft. seine used, mesh 3/8 inches, bar measurement.

TABLE 6. RESULTS OF HATCHERY EXPERIMENTS TO DETERMINE THE EFFECT OF JAW-TAGGING ON GROWTH RATE

	Tagged		Un-tagged [1]	
	Number	Ave. Total Length (inches)	Number	Ave. Total Length (inches)
Northville Hatchery Brook Trout				
Measured Oct. 7, 1935	100	4.0	100	4.0
Remeasured Apr. 2, 1936	83[2]	6.8	100	6.6
Paris Hatchery Brown Trout				
Measured Jan. 4, 1936	202	8.8	53	8.7
Remeasured Mar. 18, 1936	179[3]	8.9	52[3]	8.7

[1] The un-tagged fish measured as controls were random samples from the same population as the tagged fish.

[2] 17 tagged fish probably lost through merganser predation.

[3] 23 tagged and 1 un-tagged fish died during the sub-zero weather in February. No deaths since then.

TABLE 7 GROWTH OF WILD BROOK TROUT OF VARIOUS SIZE GROUPS AT DIFFERENT "SEASONS"

Size Group (inches)	2-3 ⅞	4-5 ⅞	6-7 ⅞	8-9 ⅞
Grand Average "Summers" 1934, 1935				
Trout Recovered	24	75	243	22
Ave. Days Out	24.2	26.7	34.0	19.8
Ave. Increase Per Day (inches x 10)	0.09	0.09	0.10	0.08
Grand Average "Autumn" 1934, 1935				
Trout recovered	2	56	36	11
Ave. Days Out	49.0	50.1	53.8	53.7
Ave. Increase Per Day (inches x 10)	0.05	0.07	0.05	0.06
Grand Average "Early Winter" 1935, 1936				
Trout Recovered	1	31	14	6
Ave. Days Out	61.0	60.6	60.3	60.5
Ave. Increase Per Day (inches x 10)	0.02	0.03	0.02	0.03

Although a slightly different type of jaw tag was used in the Paris experiment, and the experimental subject was the brown trout instead of the brook, the results are of a similar nature, and indicate that there is no significant difference in the growth rate between tagged and untagged fish, at least under hatchery conditions. Insofar as has been determined from the literature, this is the first time that a systematic study of the effect of tagging on the growth rate of the fish has been carried out. If tagging does not interfere with the growth of the fish, growth studies made by means of tagging are valid.

In studying the growth rate of the wild fish, individuals were grouped in intervals of two inches and three arbitrary time periods were set

up. The time periods chosen were "Summer" (June 1—early September); "Autumn" (late September—mid-November); "Early Winter" (from the spawning season till mid-January).

Although approximately 776 brook trout were recovered by seining in the one and one-half years of study, only slightly more than half were tagged and recovered within one of the single time periods defined above. Growth on these particular fish has been computed as the average increase per day. The results of the computations will be found in Table 7.

The following conclusions seem to be justified by the data in the foregoing tables:

1. Growth is progressively slower from summer through early winter but there is a measurable increment during this latter period.
2. There was a slight indication that fish of two to eight inches total length grew faster during the summer and autumn periods than did those of the eight to ten inch group. All fish apparently grew at about the same rate during the early winter period.

Recoveries during the months of February, March and April have been too few to attempt an analysis of growth during late winter and early spring.

Population Density—Since the total number of fish, both tagged and untagged, was known for thirteen seine hauls made during the spawning season of 1935, an attempt was made to calculate the population of that portion of the stream in which these seine hauls were made. If it is assumed that there was no loss of tagged fish by death, or loss of tags from fish, and that all tagged fish taken from the stream by fishermen were reported, the number of tagged brook trout in the stream at the time of the 1935 spawning season may be estimated at 2,437.

From carefully counted seine hauls at several different points within one and three-quarters miles, 463 untagged brook trout and 69 tagged brook trout were obtained. The estimate of the population of this stretch of the river is made by means of the following computation:—

$$\text{Number of brook trout in stream (1.75 mi.)} = 2{,}437 \times \frac{463}{69} = 17{,}059 \text{ brook trout.}$$

From this result it may be determined that the number of brook trout (size range four to ten inches) per mile of stream in the region of Lovells is approximately 9,700. From the same figure, the number per acre is approximately 700.

The following problems are among those being studied at present by means of tagging experiments conducted by the Institute for Fisheries Research:

1. The applicability of the scale method of growth determination with respect to different species is being tested by scale samplings from trout and other game fish both on tagging and on recovery. The combined data when correlated with length measurements taken at the same times should yield important information on the relationship between scale growth and body growth.
2. The tagging of 500 hatchery fish and 500 wild fish early this spring on the North Branch will, we hope, make possible a comparison of the possible differences in the growth rate, the survival, and the migration habits of the two types of fish.
3. Tagging of several hundred game fish in Fife Lake, Michigan, just before the opening of the season in combination with the intensive creel census there should also give us information on the population density and the growth rate of the species tagged.

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ATLANTIC SALMON PARR OF THE WEST COAST RIVERS OF NEWFOUNDLAND

DAVID L. BELDING

Boston University School of Medicine, Massachusetts

In 1936 through the courtesy of the Newfoundland Fisheries Research Commission an opportunity was afforded to study the salmon parr in six small rivers of the West Coast of Newfoundland. The results of our observations on the age, growth, and characteristics of these parr are presented in this paper.

Purpose. The purpose of this study was threefold:

1. To supplement the investigations of the Newfoundland Fisheries Research Commission on the adult salmon of the West Coast and to verify the river ages and lengths of the parr, as calculated by the scale readings of the adult salmon.
2. To compare the age, growth, and characteristics of the parr of the several rivers in respect to river environment.
3. To compare the growth of the Newfoundland parr with those of the Canadian rivers of the Gulf of St. Lawrence.

METHODS OF INVESTIGATION

Collection of Parr. The parr were taken within three miles from the mouths of the rivers. The lower waters were selected because of accessibility and for the sake of uniformity. Collections from restricted areas are open to the objection that they may not be typical of the entire river. However, these small rivers apparently have a uniform environment. It has been our experience from previous observations that there is usually little difference in the growth of the parr in the various sections of a small river, whereas in large rivers, which have a diversified environment, there is considerable variation.

Since the parr were taken by angling, practically no small parr of the 0-plus and 1-plus year groups have been included in our collection.

A total of 196 parr, of which 191 were in the 2-plus and 3-plus year groups, were obtained from the six rivers, which represent only the southern quarter of the West Coast and constitute less than one-quarter of all the salmon rivers of the West Coast. The small number of specimens for the individual rivers renders the results reported in this paper tentative rather than final.

Length and Weight. It has been our experience that parr which are taken with the rod are above the average size of their particular year class. Likewise, parr show the greatest increase in length during the first part of the summer. For these reasons the actual length of these

parr, which were taken about July first, is probably only slightly less than that of the average parr of the same age class at the completion of the year. However, the actual length of the parr is disregarded in our determinations of river growth, which are based on the calculated lengths for each year, as determined by scale readings.

All measurement and weight determinations were made on parr preserved in formaldehyde. In order to correspond to the two methods of measuring adult salmon in Canada and Newfoundland, two length measurements were made: (1) the total length from the snout to a point midway between the two extremities of the tail, and (2) the mid-tail length, from the snout to the end of the mid-spine of the tail. The total and mid-tail lengths are expressed in centimeters and the weights in grams.

From the weight and length the coefficient of condition of the parr may be calculated according to the formula of Menzies, in which the coefficient of condition is equivalent to the weight in grams divided by the cube of the length in centimeters. Since the coefficient of condition depends upon the solidity of the flesh or upon the contour of the parr, it is of value in comparing the parr of the different rivers.

Scale Readings. The scales were taken from the shoulder of the parr just anterior to the beginning of the dorsal fin and halfway between the lateral and the mid-dorsal lines. This location was selected since the scales of the adult salmon in Canada and Scotland are taken from the shoulder. It has the disadvantage that the scales are smaller and the river ages less distinct, especially the first year, than in the scales taken from the posterior third of the body, where they first make their appearance. It has the advantage that this part of the body does not change proportionally as the parr increases in size. The river years are determined by the winter bands in the same way as the sea-life years of the adult salmon. The same difficulties in scale reading are encountered as in the adult salmon, a small percentage of the scales being difficult to interpret accurately.

Length Calculations. Over any appreciable length of time the scale increases in size proportionally to the growth of the parr. It is possible, therefore, by knowing the length of the parr to calculate its size at yearly intervals, by measuring the distances from the center of the scale to the anterior edge and to the outer edge of each winter band. Ten well-formed scales were measured for each parr.

In calculating the yearly lengths the scale proportional method described by Belding (1) was employed. It is a modification of the scale proportion method commonly used for adult salmon by European investigators. The modified method allows for two facts: (1) the length of the parr when the scale is first formed, and (2) the initial size of the scale. The length of the parr when the scale is first secreted in the shoulder location is 2.85 cm. for the total length and 2.75 cm. for

the mid-tail length. The scale when first secreted does not start at zero but at a size of .0513 mm. Allowing for these two facts, the length of parr at yearly intervals may be calculated by the following formula, where S is the length of the scale, S_1 the length at the outer edge of the first winter band, L the length of the parr and L_1 the calculated length at the end of the first year.

$$\frac{L - 2.85 \text{ cm.}}{L_1 - 2.85 \text{ cm.}} = \frac{S - .051 \text{ mm.}}{S_1 - 0.51 \text{ mm.}}$$

Anatomical Characteristics. The sex and the number of vertebrae, pyloric appendages and gill rakers were recorded for each parr. Length and width measurements, designed to give a contour picture of the parr, were made at selected anatomical sites. When these contour measurements were reduced to percentile figures and corrected for changes in size, it was possible to compare the external anatomical characteristics of the parr of the six rivers.

Adult Salmon. Data on 350 adult salmon taken from the West Coast rivers and shores in 1931 to 1934 inclusive were furnished by Dr. Harold Thompson of the Newfoundland Fishery Research Commission. These returns covered the West Coast from Port-aux-Basques to Hawks Bay, but for the most part were from the south of the Bay of Islands in the neighborhood of the six rivers in the Bay St. George section. These data gave information as to the sea-life classes of maiden salmon, the proportion of previously spawned salmon, the years of river life, and the length of various aged parr and smolt, as calculated by scale readings.

The Rivers

The six rivers of the West Coast lie within a distance of 75 miles north of Port-aux-Basques along the shore of the Bay of St. George, into which some eleven salmon rivers flow. This section comprised about one-quarter of the West Coast. With the exception of the Great Codroy River, they are all small rivers, the length of the main stream suitable for salmon fishing being less than 20 miles. The volume of water, which spreads over a wide stream bed, is insufficient for canoeing in the summer and the streams are readily forded by fishermen in hip boots.

Four of the rivers, Crabb's, Middle Barachois, Robinson's, and Fishell's, enter the Bay of St. George so near together that the outlets are within the short distance of 13 miles. These rivers closely resemble each other in their superficial characteristics. They have wide stream beds of gravel and stone, a fairly rapid flow, a shallow depth, and numerous small pools. They flow through the same type of wooded and hilly country. In their lower reaches they flow through farm, pasture, and woodland. At their outlets are shifting sand and

gravel bars. With the exception of Crabb's River, which has a broad estuary studded with many small islands, the rivers have only about one-third of a mile of tidal water.

The Great Codroy River, which is situated 25 miles north of Port-aux-Basques, is the largest of the six rivers. It is formed by the junction of the North Branch and the South Branch and flows through farm and woodland for a distance of nine miles to enter a long estuary some nine miles in length. The North Branch has its origin in Codroy Pond and flows for a distance of 14 miles along the railroad to join the South Branch, a slightly smaller but somewhat longer stream, in a broad valley with open farm land. The stream bed is wide, the bottom gravel, stone, and ledge, and the volume of water several times that of the other rivers, affording ample facilities for canoes and boats.

Grand Bay River, the smallest of the six rivers, flows into a small, deep inland bay about one and one-half miles north of Port-aux-Basques. The river enters a narrow arm of tidal water about one-third of a mile in length after passing through a rocky ledge in a series of five small pools. Above these pools the stream spreads out to a width of 125 feet over sand, mud, and gravel bars. It has a small volume of water, a moderate flow, and in its lower reaches has low banks lined with bushes and scattering small trees. The physical characteristics of this river are quite distinct from those of the other rivers.

The Adult Salmon of the West Coast

A comprehensive account of the parr of the West Coast rivers should include information about the adult salmon. The following data upon the character of the West Coast salmon for the years 1931 to 1934 inclusive were obtained through the courtesy of the Newfoundland Fishery Research Commission.

Sea-Life Classes. Table 1 gives the sea-life classes at the time of the first spawning of both maiden and previously spawned salmon. Of the 350 salmon, 80 per cent were maiden salmon with the following distribution: grilse 34.3 per cent; two-plus sea-life salmon 44.3 per cent; and three-plus sea-life salmon 1.4 per cent; and 20 per cent were previously spawned salmon.

TABLE 1. SEA-LIFE CLASSES OF WEST COAST SALMON

Sea-Life Classes of Salmon	NUMBER			PER CENT		
	Maiden	Spawned	Total	Maiden	Spawned	Total
1-plus	120	15	135	42.8	21.4	38.6
2-plus	155	42	197	55.4	60.0	56.2
3-plus	5	10	15	1.8	14.3	4.3
4-plus	0	3	3	0.0	4.3	0.9
Total	280	70	350	100.0	100.0	100.0

Maiden Salmon. The maiden salmon are nearly all grilse and two-plus sea-life salmon, the proportion of three-plus sea-life salmon, 1.8 per cent, being negligible. Practically all the large fish are previously spawned salmon. The large proportion of small salmon places the West Coast rivers in the class of "small salmon" rivers, in which the population of maiden salmon is composed almost entirely of grilse and two-plus sea-life salmon.

Since the number of grilse depends upon the proper sampling of the catch and upon the source of the material, whether from the shore nets or from the anglers, the returns usually represent minimum figures. Likewise the percentage of grilse varies from year to year. During the four years from 1931 to 1934, it varied from 24.2 per cent to 46.4 per cent. It may be safely concluded that in the West Coast rivers grilse make up at least one-third of the total catch and two-fifths of the maiden salmon.

Spawned Salmon. The high percentage of previously spawned salmon is a characteristic of the adult salmon of the West Coast rivers of Newfoundland. The first part of Table 2 gives the percentages for the total catch and for the various sea-life classes. The percentage of grilse which return to spawn a second time is about one-half that of the two-plus salmon. There is considerable variation from year to year in the proportion of previously spawned salmon, and furthermore this variation is not consistent for grilse and two-plus salmon. Of the 70 previously spawned salmon, 15 had spawned twice or more, 2 three times or more, and 1 four times.

The second part of Table 2 gives a comparison with the Canadian salmon of the Gulf of St. Lawrence. In this comparison it is necessary to exclude grilse, since grilse are either few or are not adequately recorded in the Canadian records. The Canadian rivers have been grouped into "large salmon" rivers, in which there are relatively few grilse and a large proportion of three-plus sea-life salmon, and "small salmon" rivers, in which there are an appreciable number of grilse and two-plus sea-life salmon and but few three-plus sea-life salmon, as in the West Coast rivers of Newfoundland.

TABLE 2. PERCENTAGE OF PREVIOUSLY SPAWNED SALMON

Source	Per Cent Spawned
West Coast of Newfoundland	
Sea-Life Classes	
1-plus sea-life Grilse	11.1
2-plus sea-life Salmon	21.3
2-plus and 3-plus sea-life Salmon	24.5
Total Catch	
Including Grilse	20.0
Excluding Grilse and Salmon which first spawned as grilse	25.6
Excluding Grilse	30.4

Canadian Gulf of St. Lawrence (excluding Grilse)	
Canadian Rivers	
"Large Salmon" Rivers	**8.8**
"Small Salmon" Rivers	**6.6**
Canadian Coast	
East Coast of New Brunswick	**7.5**
Bay of Chaleur	**8.4**
Gaspe Peninsula	**6.2**
Newfoundland Gulf of St. Lawrence (excluding Grilse)	
West Coast of Newfoundland	**30.4**

River Years. The percentile distribution of the years of river life as determined by scale reading is given in Table 3. Practically two-thirds of the salmon leave the river at or before the end of the third, year seven per cent leaving at the end of the second year. The remaining one-third for the most part leave at the end of the fourth year, although some six per cent remain until the end of the fifth year and an occasional salmon does not leave until after the sixth year. The average duration of river life is 3.34 years. Although the data in Table 3 suggest that the maiden salmon leave earlier than the spawned salmon and the grilse earlier than the 2-plus sea-life salmon, the slight differences are well within the realm of experimental error.

TABLE 3. PERCENTILE DISTRIBUTION OF RIVER AGES OF WEST COAST SALMON

		Salmon		Sea-Life Class at First Spawning		
River Years	**Total**	**Maiden**	**Spawned**	**1-plus Grilse**	**2-plus Salmon**	**3-plus and 4-plus Salmon**
2	7.1	7.5	5.7	5.2	7.6	16.7
3	57.4	57.8	55.7	64.5	52.3	61.0
4	29.8	29.7	30.0	26.7	33.0	16.7
5	5.4	4.6	8.6	2.9	7.1	5.6
6	0.3	0.4	0.0	0.7	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Number	350	280	70	135	197	18
Average Years	3.34	3.33	3.42	3.29	3.40	3.11

Calculated Lengths of Parr, Smolt, and Salmon. The Newfoundland Fisheries Research Commission has calculated the length of the salmon during the several years of river and sea-life by the commonly accepted scale proportion formula, which does not take into consideration the length of the parr when the scale is first formed. Since 65 per cent of the West Coast salmon terminate their river life at the end of their third year, only the first three years of river life are given in Table 4. The parr lengths are calculated from 148 maiden salmon (74 grilse and 74 two-plus sea-life salmon) and the smolt lengths are calculated from 169 maiden salmon (94 grilse and 75 two-plus sea-life salmon).

TABLE 4. CALCULATED LENGTHS FOR RIVER AND SEA YEARS OF WEST COAST SALMON

	Number of Salmon	Length (cm.) Total	Mid-tail
River Length			
Parr			
1 year	148	3.76	3.58
2 year	148	7.78	7.29
3 year	148	12.74	11.82
Smolt			
2 year	15	11.58	10.81
3 year	96	12.85	11.93
4 year	53	15.12	14.02
5 year	5	15.99	14.80
Average	169	13.55	12.58
Sea Length			
1-plus Grilse			
1 year			
1-plus year	92	51.85	50.10
2-plus Salmon			
1 year	74	44.72	43.17
2 year	74	69.37	67.48
2-plus year	74	74.89	72.85

Length and Weight of West Coast Salmon Parr

In Table 5 the mean length and weight of the parr of the six West Coast rivers are tabulated by age classes. Nearly all the parr fall in the 2-plus and 3-plus classes. In three rivers the number of parr in the 3-plus class is too small for comparative purposes. Little difference is found in the average lengths and weights, irrespective of whether the average is taken per river or whether it is obtained by weighting the number of parr.

TABLE 5. NUMBER, LENGTH, WEIGHT, AND RIVER YEARS OF WEST COAST PARR

	1-plus Parr				2-plus Parr			
Rivers	Number	Total Length (cm.)	Mid-Tail Length (cm.)	Weight (grams)	Number	Total Length (cm.)	Mid-Tail Length (cm.)	Weight (grams)
Codroy	2	7.60	7.15	4.10	19	11.00	10.08	11.82
Robinson's	..	....	....	....	19	11.21	10.31	12.25
Crabb's	..	....	....	....	42	11.85	10.99	14.00
Grand Bay	1	7.90	7.40	4.20	6	11.88	11.03	16.57
Fishell's	..	....	....	....	22	12.65	11.69	17.78
Middle Barachois	..	....	....	....	26	13.36	12.40	21.12
Average per Parr	3	7.70	7.23	4.13	134	12.07	11.15	15.56
Average per River	..	....	....	....	....	11.99	11.08	15.59

TABLE 5. NUMBER, WEIGHT, AND RIVER YEARS OF WEST COAST PARR—(Continued).

Rivers	3-plus Parr				4-plus Parr			
	Number	Total Length (cm.)	Mid-Tail Length (cm.)	Weight (grams)	Number	Total Length (cm.)	Mid-Tail Length (cm.)	Weight (grams)
Codroy	3	12.80	11.80	18.53	..	.....	.....	.....
Robinson's	28	12.39	11.46	16.73	..	.....	.....	.....
Crabb's	3	13.40	12.47	20.37	..	.....	.....	.....
Grand Bay	9	13.98	12.89	26.52	1	17.00	15.80	49.00
Fishell's	5	13.38	12.38	21.08	1	14.60	13.60	23.60
Middle Barachois	9	14.54	13.56	27.26	..	.....	.....	.....
Average per Parr	57	13.14	12.17	20.61	2	15.80	14.70	36.30
Average per River ...	..	13.42	12.43	21.75	..	.....	.....	.....

Length. The relative length of two-plus parr for the several rivers is shown in Table 6, in which the Great Codroy River with the smallest parr is given the value of 100 and the mean lengths of the parr of the other rivers are expressed in terms of per cent increase over the Great Codroy River. Of the four rivers which are situated close together, the Middle Barachois River has the largest and Robinson's River the smallest parr. Considerable difference is also found in the length of the parr of Grand Bay River and the Great Codroy River, which differ in environment and which are situated in the southern part of the coast.

TABLE 6. RELATIVE LENGTHS AND WEIGHTS OF THE TWO-PLUS PARR OF WEST COAST RIVERS (IN TERMS OF PER CENT)

Rivers	Total Length	Mid-Tail Length	Weight	Coefficient of Condition (Average for Both Lengths)
Codroy	100.0	100.0	100.0	107.6
Robinson's	101.9	102.3	103.7	104.8
Crabb's	107.7	109.0	118.4	100.0
Grand Bay	108.0	109.4	140.2	117.3
Fishell's	115.0	115.9	150.3	105.1
Middle Barachois	121.5	122.9	178.7	105.2

Weight. In Table 6 the relative weights of two-plus parr in the several rivers are represented in the same way as the lengths. The results are similar except that the weights naturally show a greater divergence.

Coefficient of Condition. The coefficient of condition is calculated by dividing the weight of the parr in grams by the cube of its length in centimeters. Its numerical value depends upon whether it is calculated on the basis of the total or of the mid-tail length. The average coefficient of condition for the 137 two-plus parr is 0.885 for the total length and 1.123 for the mid-tail length. It is slightly greater for the 57 three-plus parr, 0.908 and 1.143 respectively.

The coefficient of condition either is an index of the solidity of the fish or indicates differences in contour. With the exception of Grand Bay River, Table 6 shows little variation in the several rivers. Minor

differences may be attributed to dehydration and formaldehyde fixation. The coefficient of condition is not associated with the rapidity of growth, since it is the same in the fast-growing parr of the Middle Barachois River and in the slow-growing parr of Robinson's River. Also when the rivers are arranged according to the value of the coefficient of condition, the order does not correspond to the rapidity of growth.

The coefficient of condition in the Grand Bay River parr is far above the average, being for the two-plus parr 0.988 and 1.235, and for the three-plus parr 0.971 and 1.238. These figures mean that the parr of Grand Bay River are relatively heavier than those of the other rivers. A comparison of the contour measurements of Grand Bay River parr with those of other rivers indicates that the deeper contour of the Grand Bay parr accounts for this difference.

Calculated Growth of Parr

The calculated lengths of the parr of the six rivers for the first three years of river life are given in Table 7. The lengths of the parr at the end of each year have been calculated from scale and parr measurements. The rivers have been arranged in order of the rapidity of growth. The arrangement checks closely with the order in Table 6, which is based on the actual measurement of the two-plus parr. The order is reversed in Grand Bay and Crabb's Rivers, which have nearly the same rate of growth. There is a rather wide range between the slow growth in the Great Codroy River and the fast growth in the Middle Barachois River.

TABLE 7. CALCULATED LENGTHS OF PARR DURING FIRST THREE YEARS OF RIVER LIFE

	TOTAL LENGTH (cm.)				MID-TAIL LENGTH (cm.)			
	River Years			Annual Gain after	River Years			Annual Gain after
Rivers	1	2	3	First Year	1	2	3	First Year
Middle Barachois	5.3	9.6	13.9	4.3	5.0	9.0	12.8	3.9
Fishell's	5.3	9.3	13.3	4.0	5.0	8.7	12.4	3.7
Crabb's	5.2	8.8	12.4	3.6	4.9	8.2	11.5	3.3
Grand Bay	5.0	8.6	12.2	3.6	4.7	8.0	11.3	3.3
Robinson's	4.8	8.2	11.6	3.4	4.5	7.6	10.7	3.1
Codroy	4.7	7.9	11.1	3.2	4.4	7.4	10.3	3.0
Average per Parr	5.1	8.8	12.5	3.7	4.8	8.2	11.6	3.4
Average per River ..	5.0	8.7	12.4	3.7	4.8	8.2	11.6	3.4

Smolt Length. The six rivers show considerable variation in the total length of the smolt, Great Codroy 12.2 cm., Robinson's 12.5 cm., Grand Bay 13.4 cm., Crabb's 13.4 cm., Fishell's 14.3 cm., and Middle Barachois 14.9 cm. The size of the smolt depends upon the duration of river life and the rapidity of growth.

Table 8 gives a comparison of the rate of growth of the three-year and of the four-year and five-year smolt for the several years of river

life. In this instance more rapid growth enables the three-year smolt to attain approximately the same size as the older smolt.

Calculated Growth of Parr from Adult Salmon. The lengths of the parr at the various years of river life, as calculated from the scales of the adult West Coast salmon by the simple proportion method, are compared in Table 8 with the lengths as determined from the actual parr. It is interesting to note that the calculated lengths of the smolt and the three-year parr are practically the same as the actual lengths but that, since no allowance is made for the size of the parr at the time of the start of the scale, the first two years' lengths are inaccurate. This represents perhaps the first instance in the literature where the calculated lengths of parr from adult salmon scales have been checked against actual parr measurements.

TABLE 8. CALCULATED TOTAL LENGTH (CM.) OF PARR AT EACH YEAR OF RIVER LIFE

	River Years				
	1	2	3	4	Smolt
3-year Smolt	5.5	9.6	13.6	*17.6	13.6
4- and 5-year Smolt	4.3	7.3	10.4	13.4	13.4
Total Smolt as Calculated:					
(1) From Parr	5.1	8.8	12.5	*16.2	13.5
(2) From Adult Salmon	3.8	7.8	12.7	....	13.6

* Theoretical length if all parr remained in river until the end of the fourth year.

Years in River. Three methods are available for estimating the duration of river life: (1) the scale readings of adult West Coast salmon, (2) the proportion of three-plus and four-plus parr to the number of two-plus parr, and (3) the length of the parr at the end of the third year. The scales of the adult salmon of the West Coast showed an average of 3.34 river years. Calculations, based on the number of parr of the different age classes in the river, gave an average of 3.38 years, and those based on increased size of the smolt over that of the three-year parr, 3.27 years. The average calculation for the parr, 3.33 years, checks closely with the results from the adult scales. The rivers vary considerably in the proportion of two-plus and three-plus parr, Robinson's and Grand Bay Rivers having a greater proportion of four-year smolts than the other rivers.

Comparison with Parr of Canadian Rivers. Table 9 gives a comparison of the West Coast of Newfoundland parr with the parr of some of the Canadian rivers of the Gulf of St. Lawrence. These rivers show marked diversity in the growth of the parr. The parr of the West Coast of Newfoundland are above the average in rapidity of growth.

TABLE 9. COMPARISON OF GROWTH OF PARR IN NEWFOUNDLAND AND CANADIAN RIVERS

River	Length (cm.) at Years of Age 1	2	3
Restigouche System			
Little Main Restigouche	4.4	8.0	11.7
Kedgwick	4.3	7.8	11.3
Patapedia	4.6	7.9	11.3
Upsalquitch	4.5	7.5	10.5
Matapedia	5.0	9.2	13.4
Margaree			
Southwest Margaree	6.5	14.0	....
Lower Northeast Margaree	5.8	11.0	*16.2
Upper Northeast Margaree	5.0	9.1	*13.2
Six Small Rivers of Cape Breton	5.4	9.8	*13.7
Moisie River	4.3	7.4	10.6
Bonaventure	4.5	7.9	11.3
Dartmouth	4.4	7.5	10.9
York	4.6	7.7	10.9
St. John (Gaspe)	4.1	6.5	8.6
Six West Coast Rivers of Newfoundland	5.1	8.8	12.5

* Theoretical growth, if parr remained in river for three years; no actual measurements made.

Characteristics of Parr

Vertebrae. Hubbs[2] reports that warm water forms of a species of fish tend to have fewer vertebrae than the forms inhabiting cooler water, since in warm water the addition of somites proceeds faster but terminates sooner, and that an increased number of segments is associated with protracted development. Therefore, environmental conditions during embryonic development would appear to affect the number of vertebrae. Table 10 shows the variation in the number of vertebrae in the parr of the six rivers. In the Grand Bay and the Great Codroy Rivers, which have different environmental conditions from the other four rivers, the mean number of vertebrae of the parr is 57.8 and 59.2 respectively, as compared with 60.1 in the other four rivers. The difference of one vertebra is of statistical significance as the range is rarely over three. There is no difference between the hatches of 1933 and 1934. The differences in these rivers suggest that the vertebral count may be an important method of distinguishing the salmon of various rivers.

Gill Rakers. McGregor[3] in the King salmon found that he could differentiate the salmon of the Sacramento and Klamath Rivers by the number of gill rakers on the first brachial arch, 23.5 and 27.4 respectively, and that the dividing line lay between 24 and 25. The gill rakers on the West Coast of Newfoundland Atlantic salmon parr in Table 10 averaged 15.0 and showed no appreciable difference in the several rivers, ranging from 14.7 to 15.1.

Pyloric Appendages. McGregor[3] found that the King salmon of the Klamath River averaged 132.2 pyloric appendages and those of the Sacramento River 176.4, the frequency curves separating sharply at 154. The Atlantic salmon of the East Coast of New Brunswick give an average of 55.4. In Table 10 the number of pyloric appendages in the parr of the West Coast of Newfoundland averaged 52.4. With the exception of Grand Bay River, there was little variation in the rivers.

TABLE 10. NUMBER OF VERTEBRAE, GILL RAKERS, AND PYLORIC APPENDAGES

Rivers	No. of Parr	Vertebrae Mean	Max.	Min.	No. of Parr	Gill Rakers Mean	Max.	Min.	No. of Parr	Pyloric Appendages Mean	Max.	Min.
Codroy	22	59.2	60	58	19	14.9	16	14	22	53.8	65	33
Robinson's ...	47	60.0	61	59	45	15.1	16	14	46	53.4	63	38
Crabb's	45	59.6	60	59	44	14.7	16	13	44	52.7	69	36
Grand Bay	15	57.8	58	57	13	14.9	15	14	15	43.0	59	31
Fishell's	27	60.3	62	59	26	15.0	17	14	25	54.4	74	36
Middle Barachois ..	33	60.3	61	59	34	15.1	16	14	34	52.5	68	34
Total	189	59.7	62	57	181	15.0	17	13	186	52.4	74	31

Contour Measurements. The body configuration of the parr may be defined by a series of measurements using certain anatomical landmarks. The parr of the four rivers with a similar environment show little variation in form, but those of the Grand Bay and Great Codroy Rivers have an appreciably different contour. These differences are particularly noticeable in respect to percentile width and thickness. The Grand Bay parr are the widest and chunkiest, the Great Codroy parr next, and those of the other four rivers the least. The difference in contour is associated with the number of vertebrae and the coefficient of condition. The Grand Bay parr have the smallest number of vertebrae (57.8), by far the highest coefficient of condition, and the greatest percentile width and thickness. The Great Codroy parr have the second smallest number of vertebrae (59.2), the second highest coefficient of condition, and the second greatest percentile width and thickness. The parr from the other four rivers do not materially differ in any of these respects.

Sex. The 196 parr are about equally divided as to the sexes, but when grouped by age classes a different picture is presented. The sex distribution in the two-plus class, which represents the normal population before any appreciable number have left the river, indicates that the normal ratio of males to females is 1: 1.25 and that there is an excess of females during the first years of river life and probably at the time of hatching. On the other hand, in the three-plus class the ratio of males to females is 1: 0.69, which favors the view that the males remain in the river longer than the females. If these rather meager figures are correct, it is an interesting speculation whether the

longer duration of river life for the male parr is correlated with the high proportion of males among the grilse and the low proportion of males among two-plus sea-life salmon.

No appreciable difference in the length and weight of the male and female parr was found. The total lengths for 93 males and 98 females of the two-plus and three-plus classes were 123.4 mm. and 124.3 mm. respectively; the corresponding weights were 17.05 grams and 17.09 grams; and the coefficients of condition were 0.907 and 0.891.

Summary

1. The growth and characteristics of the salmon parr from six representative rivers of the West Coast of Newfoundland are recorded.

2. The adult salmon of the West Coast are characterized by (1) a high proportion of grilse, (2) few three-plus sea-life salmon, and (3) a high percentage of previously spawned salmon. The West Coast rivers are "small salmon" rivers. Grilse are numerous, three-plus sea-life salmon are scarce, and practically all the large salmon are previously spawned fish.

3. The growth of the parr varies widely in the six rivers, but is above the average for the Canadian rivers of the Gulf of St. Lawrence. Four rivers have the same general type of environment and two have quite different ecologic conditions. Yet the fastest growing parr and next to the slowest growing parr in this series come from two neighboring rivers, which superficially appear to have the same environment.

4. The length of the parr at the several years of river life, as calculated by the commonly used proportion method from the scales of the adult salmon, corresponds closely to the actual length of the three-year-old parr, but is considerably lower than the actual lengths at the first two years, since the method does not allow for the size of the parr at the start of scale formation.

5. The coefficient of condition of the parr, as determined from length and weight, is the same in the four similar rivers irrespective of differences in the rate of growth. It is greater in the parr of the two dissimilar rivers. The higher coefficient of condition of the parr in these two rivers, especially those of Grand Bay River, is associated with a smaller number of vertebrae and a relatively deeper body contour than in the parr of the four other rivers.

6. The duration of river life, whether determined from the adult salmon or from the parr, is about three and one-third years.

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Discussion

Dr. Huntsman: What material did Dr. Belding use for determining possible differences in growth between the male and the female parr?

Dr. Belding: If you remember, it was roughly about 98 male and 94 or 95 female.

Dr. Huntsman: You used the whole material?

Dr. Belding: Yes.

Dr. Huntsman: Wouldn't you want to use the material for the first or second year?

Dr. Belding: Well, that was on size—or did you refer to the percentage?

Dr. Huntsman: Any possible difference in rate of growth between the two, as explaining why there were more males.

Dr. Belding: You mean should I not have included second and third plus groups? I am a little bit hazy as to the point of your question.

Dr. Huntsman: You had a slide showing that the males and females apparently reached the same size and the same weight—there was no difference. There is a possible explanation of there being more males in the later years because the females had gone out, and that might be due to the females growing more rapidly than the males. Did you analyze your material to determine whether there was more rapid growth in the females?

Dr. Belding: If you take the 2-plus group alone and the 3-plus group alone, you find they are approximately the same.

STRIPED BASS INVESTIGATIONS IN THE CHESAPEAKE BAY

R. V. Truitt and V. D. Vladykov

Chesapeake Biological Laboratory, Solomon's Island, Md.

The study of the Striped Bass, one of the most important commercial and sport fish, is the chief aim of the Chesapeake Fisheries Survey.

Up to the present time, 1,500 fish have been measured in order to establish the most common size in local waters. It was found that fish ranging from 21 to 25 cm. in standard length seem to be the most abundant in this Bay. During the last week in June, yearlings of the Striped Bass were found in several places ranging in size from 56 to 102 mm. in standard size. The most common size, however, was from 60 to 70 mm.

The study of numerical characters as to number of fin rays and vertebrae was also made. Up to the present, about 1,000 fish have been examined. The average number of soft rays in the second dorsal fin is about 11.90 while soft rays of anal fin were 10.95. It is very striking that the numbers of vertebrae as well as numbers of spines in the first dorsal fin are practically invariable. Out of 526 fish examined only one had 24 vertebrae while the remaining had 25. The hypural is included in this count. The number of spines in every single case was 9. The relatively high temperature, about 74-75°F, at which Striped Bass spawn in the Chesapeake Bay, is responsible, probably, for this consistency. In this connection, it is of interest to mention that Mr. Daniel Merriman, who is in charge of the Connecticut Striped Bass investigation, in a letter to me stated that out of 32 fish examined by him for vertebral counts, he found 27 fish with 25 vertebrae and 5 with 24.

About 1,500 stomachs of Striped Bass have been preserved for future analysis. Preliminary investigation made on about 100 stomachs shows that young Rock, about 25 cm. in length, during the summer months feed primarily on Anchovy *(Anchoviella brownii)* and young Menhaden *(Brevoortia tyrannus)*. Larger fish feed, in addition to Menhaden, on blue crabs *(Callinectes sapidus)*. Occasionally, as many as 20 to 25 small crabs are found in a single stomach. Yearling Rock feed almost exclusively on crustaceans, Mysidacea are principal group.

Tank experiments on feeding habits of our Striped Bass confirm the observations made in nature. As a rule Striped Bass do not feed on dead food.

This fall, it is planned to tag between two and three thousand Striped Bass in different places of the Chesapeake Bay in order to get more complete data on their migration.

Dr. V. D. Vladykov (Maryland): It is a distinct pleasure for me

to address you on behalf of Dr. Truitt, Director of the Chesapeake Biological Station, with regard to the work that this station is doing. I should like to make the following preliminary comments: Although I am representing Dr. Truitt I am using not his language but my own, hence Dr. Truitt is not to be blamed for any mutilation of the language. It is not really a paper that is being presented at this time; it is rather a short account of the work of the Chesapeake biological laboratory under the auspices of the Maryland Conservation Commission. The presentation to-night is from a rather selfish point of view, because we want to get some comments from experienced investigators with regard to their studies on the same subject.

Discussion

Mr. E. Lee LeCompte (Maryland): May I ask Dr. Vladykov what his range of lengths has been?

Dr. Vladykov: The majority of our young bass range from 21 to 25 centimeters. I must say that our sizes were rather artificial because during the summer months I took smaller sizes for my own purposes, because it is too expensive to take larger bass. Since last year the bass have been returning to Chesapeake Bay, and this year in many places very large catches were made around Solomon's Island.

THE DATE OF ANNUAL RING FORMATION IN THE SCALES OF THE WHITE CRAPPIE

DONALD F. HANSEN

Illinois Natural History Survey, Urbana, Ill.

I. INTRODUCTION

In the course of a study of growth of Illinois fishes a number of cases of what appeared to be summer annual ring formation were found in the scales of the white crappie. Previous investigations by other workers had shown that in most of the fishes studied, the annual rings were formed in winter or early spring. The exceptions to this rule may, however, be noted. Clark (1925) found that the grunion of the Pacific coast, *Leuresthes tenuis,* formed the annulus in the summer months and showed also that the annulus was a spawning mark. Also Schultz (1933) has worked on the date of annulus formation in the bay smelt, *Atherinops affinis oregonia,* of the Pacific coast and has reported that the first annual ring in this fish is formed in April and the second in May and June or later.

The evidence which would fix winter or spring in certain species as the time of annulus formation has been reviewed by Van Oosten (1929) and Creaser (1925).

II. THE REASON FOR STUDYING DATE OF ANNULUS FORMATION AND METHODS USED

In the case of scales of the sunfish type, it has always been assumed that an annulus was formed when growth of the fish was resumed or accelerated with the warming of the water and increased physiological activity in spring. This explanation leads one to believe that this early spring activity would give a new annulus to all the fish at the same time. Consequently, on all scales collected after this assumed early spring date, the last ring on the scale would have to be new for that year and the width of the scale outside the last annulus would represent the growth of that year. But in the present study it has been found that the date of formation is quite variable—varying from May to July—or later. So that in the fish which are late in forming a new ring the outside growth on the scale is not the new year's growth but represents the growth of the whole preceding year. Thus, if we had continued to hold to the theory of early spring formation for all the fish, confusion between the new growth and old growth would have led to errors in the age of our fish. To avoid these errors, it would be necessary to determine the latest date of formation and then only use scales collected after that date. This would also hold where there is any

intention to identify the growth zones on the scales with certain calendar years.

In the summer of 1933 a series of collections were made which showed strong indications of summer annulus formation. All of these collections were made at the same place in the Sangamon River ten miles west of Urbana. Collections were begun on June 11 and continued until September 20.

Instead of finding that the outside band of summer growth became wider and wider as the summer advanced, which would have been expected if the annulus was formed early in the spring, a few individuals were found in each collection after June 11 which showed the last annulus so close to the edge of the scale as to lead one to believe that the annuli had formed not more than 2 or 3 weeks before the date of collection. The following table shows the number of cases in which these scales appeared in the collections. Included in this table are only those on which the growth outside the last annulus was 15 per cent (or less) of the previous season's growth.

Date	*Number of fish caught*	*Number of fish with an annulus near edge of scale*
June 11	3	0
June 24	29	2
July 7	28	6
July 13	12	1
July 24	28	4
Aug. 2	25	3
Aug. 18	10	2
Sept. 7	28	2
Sept. 20	20	2

Although the annuli at the edges of the scales on the above dates appeared by their position to have formed recently, it was not proved to be the case. In regard to this Dr. Charles Creaser (correspondence) pointed out that the narrow-margined scales might have formed the annuli in spring but had grown only slightly before the date of collection. The proof of summer formation was then obtained from two series of spring and summer collections made in 1935 and 1936 from a single locality.

From these I attempted to find the principal date of annulus formation by counting the number of fish with an annulus near the scale margin, including in this category only those on which the margin outside the last annulus was *one-third or less* the width of scale growth for the preceding year. The counts of these narrow-margined scales were made for each collection of the season. Then the number of fish with narrow-margined scales for each date was expressed as a percent of the total number of fish in the catch for that date.

TABLE 1. WHITE CRAPPIES, SANGAMON RIVER AND DECATUR LAKE, 1935. PERCENTAGES OF FISH SHOWING ANNULI NEAR EDGE OF SCALE

Date of Collection	Total Number	Length Groups in Inches										ALL SIZES	
		1.6 to 3.5		3.6 to 5.5		5.6 to 7.5		7.6 to 9.5		9.6 to 11.5			
		Ratio	Per cent	Ratio	Per cent	Ratio	Per Cent	Ratio	Per cent	Ratio	Per cent	Ratio	Per cent
April 23 and 26	34	....	..	0/2	..	3/13	23	1/18	6	0/1	..	4/34	12
May 2, 8, 9, 11 and 13	21	....	..	0/1	..	0/10	0	1/7	..	2/3	..	3/21	14
May 17, 18, 21 and 22	123	13/43	30	1/18	6	13/57	23	0/3	..	1/2	..	28/123	23
June 4	53	....	..	3/14	21	11/34	32	0/5	..	..	..	14/53	26
June 25 and 26	111	....	..	37/80	46	13/28	46	0/3	..	..	..	50/111	45
July 11, 15 and 16	198	....	..	58/114	51	36/77	47	1/7	..	..	..	95/198	48
September 21	5	....	..	1/2	..	1/3	..	..	..	..	..	2/5	..
November 1	2	....	..	...	..	1/2	..	..	..	..	..	1/2	..
November 22	78	....	..	5/40	13	0/33	0	2/5	..	..	..	7/78	9

TABLE 2. WHITE CRAPPIES, DECATUR LAKE 1936. PERCENTAGES OF FISH SHOWING ANNULI NEAR EDGE OF SCALE

Date of Collection	Total Number	Length Groups in Inches								ALL SIZES	
		3.6 to 5.5		5.6 to 7.5		7.6 to 9.5		9.6 to 11.5			
		Ratio	Per cent	Ratio	Per cent	Ratio	Per cent	Ratio	Per cent	Ratio	Per cent
May 5	75	1/39	3	0/41	0	3/5	..	...	..	4/75	5
May 29 and June 4	100	12/21	57	2/61	3	2/15	13	0/3	..	16/100	16
July 3 and 5	45	1/13	8	8/30	27	0/2	..	...	..	9/45	20
July 31 and August 3	82	0/50	0	2/31	7	0/1	..	...	..	2/82	2

Now, to explain the manner in which these percentages were used, suppose that on April 30 zero percent of the fish fell within this category of narrow-margined scales, but on May 15, 100 percent of the fish fell within this category. This would mean that between April 30 and May 15, 100 percent of the fish had formed a new annual ring. Again suppose that another scale collection was made a month later on June 15 and only seventy-five percent of the fish had narrow-margined scales. The explanation of this drop would be that following the annulus formation twenty-five percent of the fish had grown enough to throw them out of the narrow-margined class. In other words the scale margins on the twenty-five percent were now more than a third as wide as for the preceding year.

The trend in annulus formation, however, as it turned out, is a more gradual process. Beginning with the April collection when the percent of narrow-margined scales is small, it has been found that this percent increases gradually through May and June, with the greatest percent probably occurring the last of June or the early part of July. These narrow-margined scales are not necessarily always the scales that have formed a new annulus, since even in the winter months these narrow-margined scales are occasionally found.

Examination of the scale samples was done with a low power binocular dissecting microscope. Measurement of the widths of the growth zones was made in the lateral field of the scale with an ocular micrometer.

III. The Date of Annulus Formation in the White Crappie in 1935

Most of the scales for this analysis were collected from the hook and line fishermen at Decatur, Illinois, and represent fish caught from both Decatur Lake and the Sangamon River just below the Decatur Lake dam. A few were obtained by seine hauls and all the November 22 catch was taken by hoop net.

Table 7 shows the dates of scale collections and percent of fish with an annulus near the edge of the scale for each date. The percentages have been calculated both for fish of different sizes and for the total catch. Reserving the study of relation of size of fish to date of formation for the moment and paying attention only to the last column in the table, we find that the percentages increased steadily from 12 percent in the last of April to 48 percent in the middle of July.

If we can accept the view that an increase in number of narrow-margined scales between two dates is due to annulus formation, then it is clearly shown that annulus formation was going on in May and June and perhaps July. The lack of a collection before April 23 makes it impossible to say whether or not formation was going on before that date. It is possible that the 12 percent which had narrow-margined scales on April 23 and 26 were slow growers of the year before, therefore, did not represent fish with new rings.

The last date of formation for 1935 has not been determined since no collections were made from July 16 to September 21. The 9 percent on November 22 may however, either mean that growth was slow in a few individuals in 1935 at Decatur or that ring formation was continued to late summer or fall. Evidence will be presented below which indicates that the latter may have been the case.

IV. The Date of Annulus Formation in the White Crappie in 1936

The collections under this date are the first of a new Decatur Lake series begun on April 3. The fish were caught with one inch mesh hoop nets which will take all sizes down to about 3.5 inches standard length.

These data have been handled exactly as that for 1935. In Table 2, the last column shows the percent of fish with annuli near the edge of the scale. The criterion for these narrow-margined scales is the same as used in the 1935 data (see Section II). Table 2 shows that from May 5 to June 4 there was an increase in narrow-margined scales and this was followed by another increase in the combined collection of July 3 and 5. Again it seems evident that an increase in percent of narrow-margined scales must mean the formation of new annual rings and so it may be concluded that the 1936 scales formed the rings in some of the fish in May and in some in June.

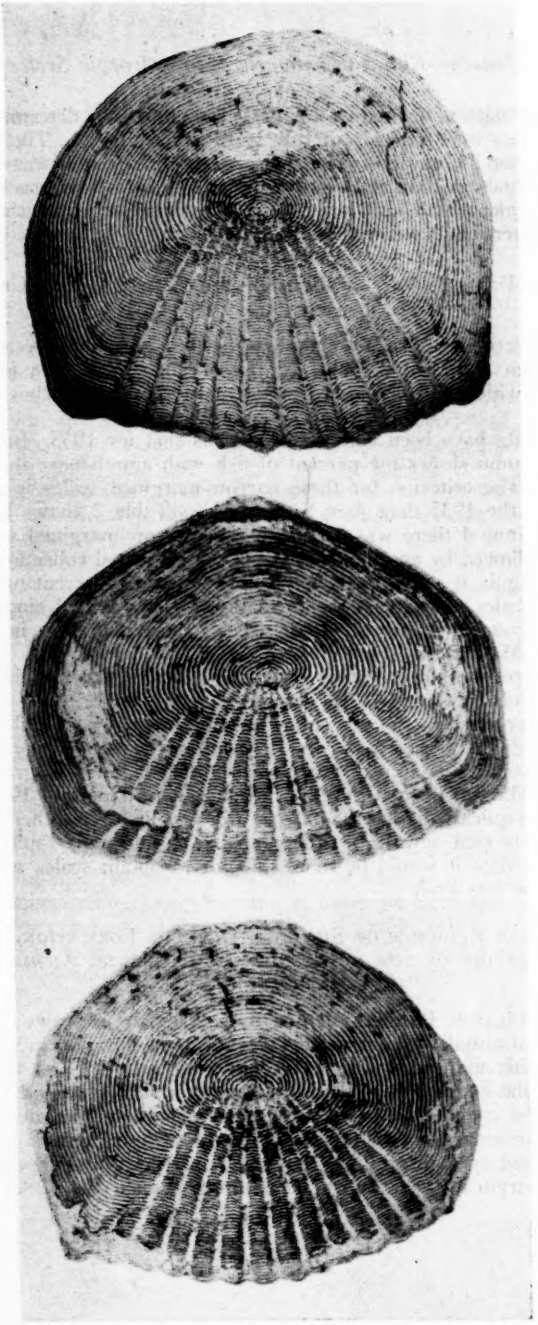
The sharp drop in percent on August 3 indicates that annulus formation was probably over by that date.

The discrepancy in the percentage of narrow-margined scales on approximate dates in the two years is of interest, and we may guess at the explanation. One explanation might be that if the scale growth was small in 1935 and normal in 1936, the margins of the late 1936 scales would more quickly exceed the *one-third or less* limit. Another explanation would be that new 1936 scale growth was unusually rapid, so that on any one date it would be more difficult to obtain scales within the *one-third or less* limit.

V. Further Evidence of Summer Annulus Formation in 1935: Absorption of the Scale Margin Preceding Annulus Formation

Plate 1, Figs. A, B, and C demonstrate that crappie scales may have two types of annuli. The annuli in Fig. A tend to conform in outline to the outside margin of the scale. The circuli (ridges on the scale) formed at the end of one year do not run completely around the scale but meet the complete circuli of the next year along the lateral fields. This is the commonest type of annulus in the white crappie.

The second type of annulus illustrated by Fig. B has been formed after the margin of the scale has been absorbed as in Fig. C. This type



of annulus is similar to the spawning mark on salmon scales described by Johnstone (1905) and that described by Creaser (1925) in the smelt. This type is by no means rare in the crappie, though extreme absorption shown in Figs. B and C is only occasionally found in certain

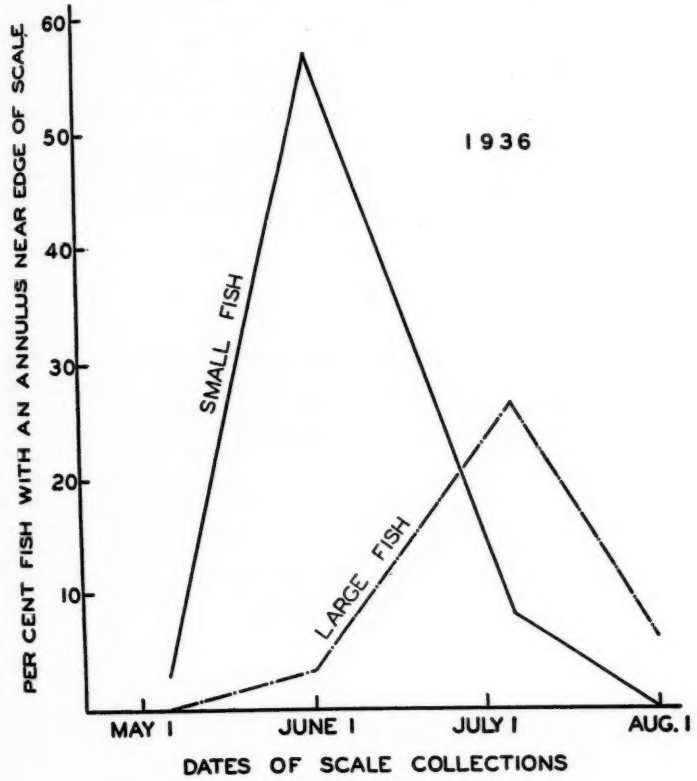


Fig. 1

places and in certain years. It was common in the Sangamon River in 1933 and again in 1935, but has hardly occurred at all there in 1936. This type of annulus is rarely found at the end of the first year.

On July 11, 1935, a large collection of specimens showed 38 per cent with more or less absorption at the outside edge of the scale. In the same collection a number showed there had been absorption preceding

annulus formation. In many of these there were as few as two to six circuli bounding the absorbed edge. Counts of narrow-margined scales on July 11 (see Table 1) showed an increase over July 25 and 26 signifying ring formation in those two weeks. It does not therefore seem out of place to suggest that many of the scales having absorbed edges on July 11 later started to grow, thereby producing new annual rings.

The November 22 collection showed a drop from 38 per cent to 2.5 per cent in number of fish with absorbed scale edges while at the same time there was an increase in the percentage of scales which had followed absorption by growth. This is shown by the following table:

Date 1935	No. of fish	Per cent of Population with Edges of scales absorbed	Edges of scales absorbed but followed by growth	Edges of scales showing no absorption
July 11				
Sangamon River	155	38.0 (59)	266.0 (40)	36 (56)
November 22				
Decatur Lake	78	2.5 (2)	47.5 (37)	50 (39)

It will be noticed that the November collection showed more scales with no signs of absorption than the July collection. This might be explained if the fish with absorbed scales had a tendency to die off in late summer and fall, especially if the absorption is a sign of starvation. Still, I believe the figures indicate that some of the fish with absorbed scale edges in July later resumed growth and produced annual rings.

Absorption at the edges of the scales did not begin until some time in June. If some of the scales produced annuli before absorption began, it must have been such a short time before that absorption removed all traces of previous formation. At least the November collection showed no cases of an ordinary annulus preceding the absorption type, when the two appeared to have both formed in 1935.

VI. Effect of Size on Date of Annulus Formation

In Tables 1 and 2 the data for 1935 and 1936 have been grouped according to the standard length of the individuals. The 1936 data, Table II, show that the small (3.6 to 5.5 inches) fish had a peak in formation about the first of June, while on the same date the large ones (5.6 to 9.5 inches) had barely begun (Fig. 1). The peak in formation in the large fish came a month later when formation in the small fish was on the decline. Our data also show that the small fish were through on August 1, somewhat before the large ones. It is possible that Fig. 1 indicates a somewhat greater difference than may actually exist for these two groups. The data would have carried more weight if collections had been available at two-week rather than four-week intervals, and had been larger. However, I believe the striking difference in the

number of narrow-margined scales between large and small fish on June 1 is certainly in the direction indicated.

Now, turning to the 1935 data, Table 1 and Fig. 2, we do not find

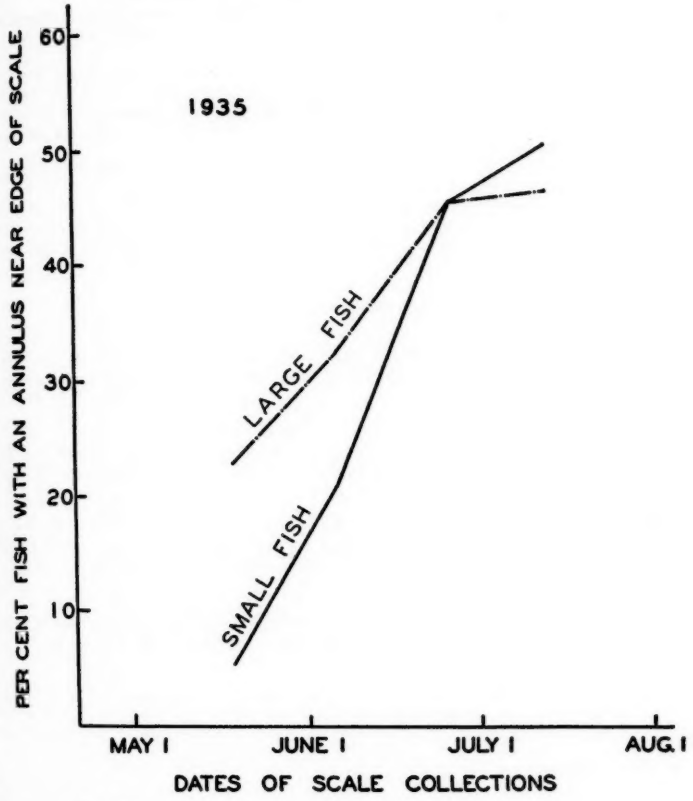


Fig. 2

the difference shown in 1936. Here it seems to be the larger fish that are forming the ring first. But this may have been because more large fish had narrow margins from the year before. It will be noticed that a dropping off in narrow-margined scales occurred about the same time in large and small fish after June 25. If there actually is a size effect in date of formation, it is possible that abnormal growth conditions as

evidenced by extreme absorption of scales prevented the size effect from showing in 1935.*

Discussion

Dr. Hazzard (Michigan): I would like to ask if any experiments are under way to determine the exact time of formation of the annulus, similar to those which have been made with respect to the whitefish.

Mr. Hansen: No. Of course I was attempting to find the exact time, but the time does not seem to be an exact time; it occurs over a range of dates. In 1935 it was in May, June and July; in 1936, in May and June and possibly in July. I do not say that the annulus is always formed at that time, but that is what our observation has shown.

Dr. Huntsman: May I ask whether the annulus is distinct from the spawning mark?

Mr. Hansen: There are two kinds of annuli in the crappie. Usually the crappie does not show the kind with the absorbed scales, and the correspondence of the absorbed scale with the spawning season made me think it might be a spawning mark.

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THE SUBMARINE PHYSIOGRAPHY AND OCEANOGRAPHICAL PROBLEMS OF THE SCOTIAN SHELF*

H. B. HACHEY

Atlantic Biological Station, St. Andrews, N. B., Canada

THE SUBMARINE PHYSIOGRAPHY OF THE SCOTIAN SHELF

The bold and rocky coast of Nova Scotia to the south is marked by numerous indentations, forming many bays and harbours. Extending all along the coast are numerous shoals and islands which form the more pronounced irregularities of the sea floor. The continental shelf extends outwards from this coast to a distance of 100 to 150 miles. The general topography of this shelf is very irregular. The submerged Laurentian valley proceeding from the Gulf of St. Lawrence, and the Fundian channel proceeding from the Bay of Fundy and the Gulf of Maine, form the east and west boundaries respectively of an irregular-shaped submarine plateau of irregular topography, which might be rightly designated as the Scotian shelf.

The more important elevations of the Scotian shelf are Sable Island, and Middle, Western, Roseway, La Have, Emerald, and Sambro banks, as well as the banks known as Banquereau, Canso, and Misaine. The submarine physiography of the Scotian shelf is illustrated in figure 1 chiefly by means of the contours of 50, 75, and 100 fathoms. With the exception of several basins of limited extent whose depths are greater, the Scotian shelf as a whole, is less than 100 fathoms below the sea surface.

A large western area of the Scotian shelf is of depths greater than 50 fathoms and less than 100 fathoms. Bounded as it is, on the north by the mainland of Nova Scotia, on the east by Canso bank, Middle Ground, and Sable Island bank, and on the west by Brown's bank, and with its greater depths extending to the edge of the continental shelf to the southward, this submarine area may be termed the Scotian Gulf. Roseway, La Have, Sambro, and Emerald banks form elevations over this portion of the sea floor.

The area of the sea floor enclosed by the Nova Scotia coast and the 50 fathom contour is approximately 15 miles in width along the south coast of Nova Scotia. The continental shelf varies from about 65 miles in width off Cape Sable (the western extremity) to 130 miles in width off Cape Breton (the eastern extremity). Consequently, the Scotian Gulf in the western portion of the shelf, not only has a submarine opening to the southward, but also has close contact with oceanic depths.

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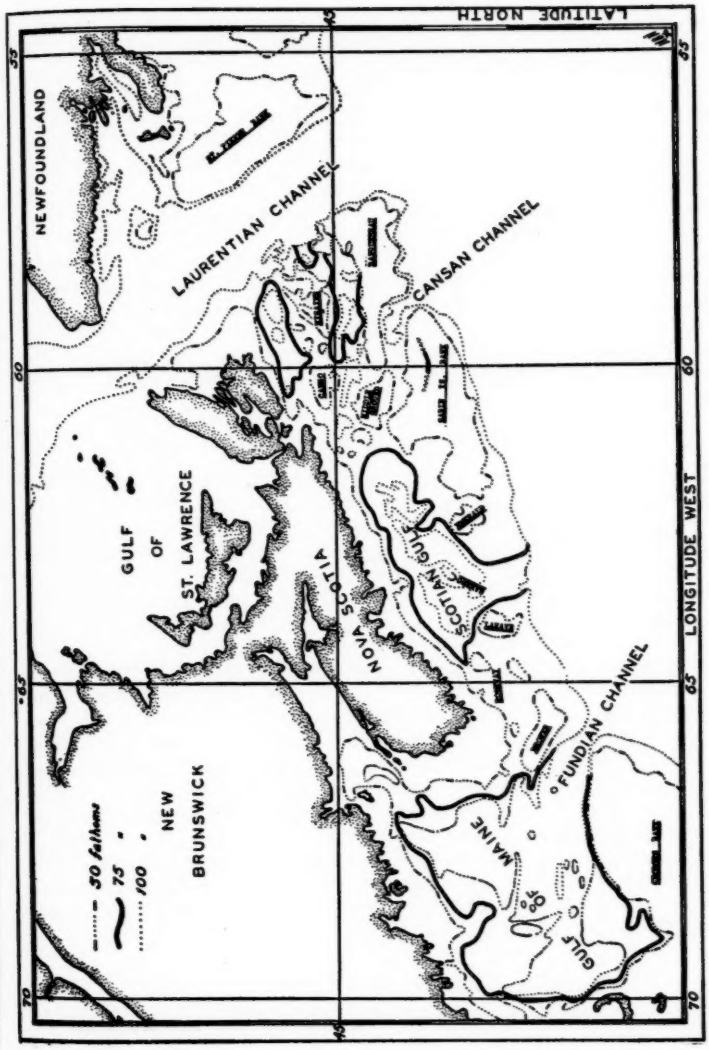
The Waters of the Scotian Shelf

Probably the most remarkable feature of the waters of the Scotian shelf is the cold water layer of a temperature less than 5.0° C. (as low and even lower than 0.0° C.). This layer which, in summer, is found at depths between 17 and 66 fathoms offshore and between 33 and 80 fathoms inshore is an effective barrier to any interchange between waters of the warmer surface layer and the deeper and warmer bottom waters. Consequently, in summer, three distinct layers of the water are readily recognized.

The submarine physiography of the Scotian shelf is of direct interest in considering the distribution of this cold water layer. It can be readily demonstrated that the production of the greater portion of this water of comparatively low temperature takes place further to the north (according to Sandstrom, 1919, in Greenland waters). It is true that the "after-winter effect" is of considerable moment in the production of a large body of cold water, as winter cooling is found to be effective to depths of at least 50 fathoms on the Scotian shelf. In following the trend of conditions from season to season however, it becomes obvious that continual enhancement of this comparatively cold intermediate water must take place by water movements from the east. From the Gulf of St. Lawrence (Sandstrom, 1919) this cold water pours out via Cape North along the coast of Nova Scotia. Coming in contact with the northeastern edge of the Scotian shelf, the westerly tendency of the waters (due to the rotation of the earth) is partly offset by resistance offered by the shallower portions of the shelf. Sable Island and Sable Island bank are particularly effective in this respect, but a considerable volume of water works its way westward between Sable Island and the main land. The particular specific gravity of this comparatively cold water allows a flooding of the shallower eastern banks, but as it proceeds westward it is forced to an intermediate level, and makes contact with the bottom only on the shallower banks and along the shallower portions of the immediate coast. Where deep submarine inlets penetrate the shelf from the Laurentian channel, these colder waters are able to exist on the shelf at the greater depths. Other than this, the more important depressions on the Scotian shelf contain waters of comparatively higher temperatures (from 5.0° C. to 8.0° C.) and of comparatively higher salinities (greater than 33.50% and less than 35.00%).

These bottom waters of comparatively higher temperatures and salinities approximate quite closely in character to the slope water as defined by Bjerkan (1919). Hence its presence in the deeper areas of the Scotian shelf indicates a penetration of slope waters within the margin of the continental shelf. This penetration has been found to be particularly effective in what has been termed the Scotian Gulf, and the explanation must be sought for in the submarine physiography of that


LATITUDE NORTH
LONGITUDE WEST
NEWFOUNDLAND
LAURENTIAN CHANNEL
CANSAN CHANNEL
GULF OF ST. LAWRENCE
NOVA SCOTIA
SCOTIAN GULF
FUNDIAN CHANNEL
MAINE
GULF
NEW BRUNSWICK
50 fathoms
75
100
60
65
70

portion of the shelf. In Figure 1 it is readily seen that depths greater than 75 fathoms persist throughout this submarine gulf and offer a ready access to the slope waters at the edge of the continental shelf. It might also be noted that this submarine gulf is the only area of such depths opening towards the south. This fact is of particular importance in a consideration of a transgression of marginal waters over the Scotian shelf (Leim and Hachey, 1935). In 1934, bottom waters of higher temperatures (as compared to the years 1932, 1933, and 1935) invaded the area of the Scotian shelf during the summer months. This invasion was particularly evident over the area of the Scotian Gulf. Further, this invasion by bottom waters culminated in a flooding of the area in late autumn by surface waters of comparatively high temperature and salinity. The distribution of these invading surface waters was roughly outlined by the boundaries of the Scotian Gulf. It would seem therefore, that the submarine physiography of the Scotian shelf was, in some indirect manner, a prominent factor in controlling the invasion of these marginal waters (i. e. those bordering the continental shelf).

Oceanographical Problems of the Scotian Shelf

The invasion of marginal waters over the Scotian shelf in 1934, was responsible for oceanographical features of the waters which, previously, had not been appreciated. The investigations of 1932, 1933, and 1935 pointed out the importance of the cold water layer of temperatures less than 5.0° C. In 1935, extremely cold water, in quantity, seemingly prevailed. The year 1934, however, indicated that invasions of marginal waters followed from the lack of, or prevented, the usual westerly movement of the cold intermediate water. Provisionally, the author has suggested that this invasion of marginal waters was of the nature of a transgression as elucidated by Le Danois (Hachey, 1936). Provisionally also, we may consider that, on the Scotian shelf, 1934 was a "warm water" year, 1935 was a "cold water" year, and in the years 1932 and 1933 "average" conditions prevailed. Such definitions are based primarily upon the temperature and volume of the comparatively cold water that is found, in summer, as an intermediate layer over the greater portion of the Scotian shelf.

All oceanographic problems of the waters of the Scotian shelf are subservient to this, the major problem—viz: What factors *fundamentally* control the variation between what we have termed "cold water" years and "warm water" years?

Summary

Features of the submarine physiography of the Scotian shelf are (a) the shallower banks in the eastern portion of the shelf which offer considerable resistance to a westerly movement of the waters proceed-

ing from the Gulf of St. Lawrence, and (b) the Scotian Gulf with a deep mouth opening to the south allowing ingress of slope waters over the shelf.

The major oceanographical problem of the Scotian shelf, concerning the factors connected with the determination of "cold water" and "warm water" years, is in part related to the submarine physiography of the Scotian shelf. In conclusion, it would seem that the Scotian shelf, with various waters infringing on its margins, and with its submarine physiography of peculiar suitability, offers an exceptional area for the solution of a major oceanographical problem.

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FOOD HABITS, RATE OF GROWTH AND CANNIBALISM OF YOUNG LARGEMOUTH BASS *(APLITES SALMOIDES)* IN STATE-OPERATED REARING PONDS IN MICHIGAN DURING 1935

GERALD P. COOPER

Institute for Fisheries Research Michigan Department of Conservation, Ann Arbor, Mich.

INTRODUCTION

Maximum production and maximum growth are the ultimate aims in the pond propagation of black bass. Important among the factors controlling production and growth are food habits, rate of growth and cannibalism. Although previous investigations have contributed considerably to our knowledge of these factors, their interrelationships and their relationship to production, it is believed that further information along these lines will give the fish culturist a better understanding of the complicated processes involved in bass propagation and will aid him in increasing his output. The following studies of the largemouth bass have been undertaken to obtain further data on the interrelationships between these basic factors in production, namely: rate of growth, food habits and cannibalism.

MATERIALS AND METHODS

The studies were based on the examinations of samples collected from the ponds at different times during the summer. The ponds examined are: two state-owned rearing ponds at Fenton (hereafter referred to as Fenton Ponds 1 and 2), the state-operated Corduroy Cord Pond at Grand Rapids and Pond AB at the Lydell Hatchery at Comstock Park.

The two Fenton ponds are of recent construction; Pond 1 was operated first in 1934 and Pond 2 in 1935. The large Corduroy Cord Pond is a relatively old, artificial pond, maintained by the Corduroy Cord Tire Company as a fire protection. The Lydell Pond was remodeled during 1934. In the fall of 1934 all four ponds were drained, the fish removed and the ponds then allowed to fill with water. No fertilizer or artificial feeding was employed in any of the ponds during the period covered by the present study. Data on the area, depth, bottom composition, water supply and vegetation of each pond are given in the first part of Table 1.

The two Fenton ponds were stocked with bass fry seined from natural lakes in Oakland County: Pond 1 was stocked with 50,000 fry during the period of June 15 to 24, and Pond 2 was stocked with 160,000 fry during the period of June 24 to July 3. The bass fry in Corduroy Cord

TABLE 1. DESCRIPTIVE DATA ON THE FOUR BASS-REARING PONDS INVOLVED IN THE PRESENT STUDY, AND NOTES ON THE COLLECTING OF SAMPLES

	Fenton Pond No. 1					Fenton Pond No. 2			Corduroy Pond		Lydell Pond			
Area (acres)	3.2					6.4			15		1			
Max. depth (ft.)	6					8			9		8			
Average depth (ft.)	3					3			4		4			
Bottom	Sand					Sand			peat and mud		Sand			
Water supply	Spring Creek					Fenton Pond No. 1			Warm Creek		Warm Creek			
Vegetation	Scant to abundant (mostly algae)					Abundant (mostly algae)			Extremely abundant (submergent types)		Scant			
Date (1935)	**June 29**	**July 5**	**July 16**	**July 30**	**Aug. 24**	**June 29**	**July 5**	**July 16**	**July 30**	**Aug. 24**	**June 21**	**July 27**	**Oct. 19**	**July 27**
Time of sampling	3to4 P.M.	9:30to10 A.M.	5to6 P.M.	3:30to4 P.M.	4to6:30 P.M.	4to5 P.M.	10to12 A.M.	6to6:30 P.M.	4to5 P.M.	5to6 P.M.	10to12 A.M.	8:30to10 A.M.	9to12 A.M.	11to11:30 A.M.
Water temp. C.	29	29	28	27	25	30	30	28	27	25	..	29	14	29
Air temp. C.	27	29	26	28	17	27	30	27	28	17	..	27	19	28

Pond were produced by natural reproduction in the pond. In November 1934, Mr. Claud Lydell stocked this pond with 302 adult largemouth bass and 6,957 adult golden shiners *(Notemigonus crysoleucas)*. The 1935 hatch of bass fry appeared about the first of June. Definite data on the number of bass fry produced in this pond were not obtained; however, it was the opinion of the Lydell Hatchery personnel that the number still far exceeded 200,000, even after 20,000 had been removed for stocking the Lydell Pond. This transfer of 20,000 bass fry from Corduroy Pond to Pond AB at the Lydell Hatchery was made on June 21.

Adult golden shiners were introduced accidentally into the Fenton ponds during the fall of 1934:—approximately 30 into Pond 1 and 400 into Pond 2. At the time of the first examination of the Fenton ponds on June 29, no shiner fry were encountered in Pond 1, but they were found in abundance in Pond 2. Similar observations were made by Mr. A. T. Stewart and members of his staff during the period of June 15 to 29. An enormous number of young shiners (estimated from sampling and observation to be several millions) was produced in Corduroy Pond. The Lydell Pond had no shiners. Possible forage fishes, other than golden shiners, were so rare in all ponds as to be unworthy of mention.

Data on the number, date, time, etc. of samplings, taken throughout the season, of the bass and shiners in these ponds are given in Table 1. It is believed that each of these collections was a close approximation to a true random sample of the young fish in the pond at the time of collecting. Each of the two October samples from the Fenton ponds was taken by hand-net when the pond was drained and the entire pond population was confined in small holding pools; the cannibal bass were separated from the non-cannibal bass, on the basis of size, before the samples were taken. Thus these October samples from the Fenton ponds include separate random samples of these cannibal and non-cannibal groups, for example: the 34 non-cannibal bass of the sample (Pond 1) represent the total 9,250 individuals of that class which were taken from the pond, while the 64 cannibals of the sample represent the total 200 individuals of the cannibal class which were taken from the pond (see footnotes to Table 2). All other samples were collected by seines which had meshes sufficiently small (1/6 inch, ¼ inch and ⅜ inch—bar measure) to capture the smaller fishes and were long enough (20 to 60 feet) to cover a sufficient area of both deep and shallow water to guarantee the capture of the larger individuals.

All fish in each sample were preserved in 10% formalin immediately and after 2 or 3 days were transferred to 70% alcohol for permanent preservation. Examinations of these samples were made during the period of December 9, 1935 to May 6, 1936. Since those samples which were collected first were likewise examined first, all of the samples had been in preservative approximately the same length of time. Since the method of preservation was identical for all collections, it is believed

that any error in lengths and weights, resulting from the failure to correct for the effect of preserving fluids, was uniform for all the samples. All lengths referred to are body or standard lengths; these were taken by placing each fish on the ruler and sighting to the nearest millimeter. In recording weights, the specimens were divided into three groups—non-cannibal bass, cannibal bass and golden shiners, and each group within each collection was weighed as a unit. The excess of preservative fluid was allowed to drain off before weighing. Weights were taken to the nearest gram.

The separation of the non-cannibal and cannibal groups among the bass was desirable due to the great differences in food habits and growth. This separation was made in part on direct and in part on circumstantial evidence. Those bass which, during the food studies were found to contain other bass in their stomachs were used to set the limits of the size range of the cannibal class; all other bass within this size range were considered cannibals, except where the smaller cannibals were unusually small in relation to the entire bass population. The records of cannibals are as follows:

> Fenton Pond 1—July 5, of the 16 specimens in the cannibal class, 14 contained young bass; July 16, of 25 specimens, 7 contained bass; July 30, 9 specimens, no bass; Aug. 24, 18 specimens, 1 bass; Oct. 17, no food studies made. Fenton Pond 2—July 5, 26 specimens, 8 contained bass; July 16, 21 specimens, 6 bass; July 30, 7 specimens, 2 bass; Aug. 24, 2 specimens, 1 bass; Oct. 31, no food studies made. Corduroy Pond—July 27, 1 specimen, 1 bass. Summary—125 specimens recorded as cannibals, of which 40 specimens (32%) contained young bass in their stomachs at the time they were collected.

From these data it appears to be a logical assumption that, during the course of the summer, most if not all of the bass within the size range designated for the cannibal class were actually cannibalistic. The cannibal classes in the October samples from the Fenton ponds were defined on the basis of size distribution of cannibals in earlier collections. Scale examinations verified the fact that the large cannibals were young of 1935.

Food studies were made on all of the cannibal bass, and either on all or on a large sample of the non-cannibal bass in each sample, except the October collections from the Fenton ponds. Only the contents of the stomachs were analyzed, the contents of the intestines not being examined. The results of the examinations were recorded for individual fish as the number of each type of organism and as the estimated percentage represented by each type. Facilities were not available to measure the volumes of food organisms in individual fish; however, the total volume of each type of organism from all non-cannibal bass and from all cannibal bass in each collection was determined by water displacement, in a centrifuge tube with which readings to the nearest 0.02 cubic centimeters could be made. In the event of several types of organisms each of too small a volume to be accurately measured, their

combined volume was measured and their respective volumes estimated. Identifications of the insect food organisms to family, genus or species were made, chiefly by Mr. J. W. Leonard of the Institute for Fisheries Research.

Results

This study is concerned with the history of the populations of each pond only during that time period included by the dates of sampling

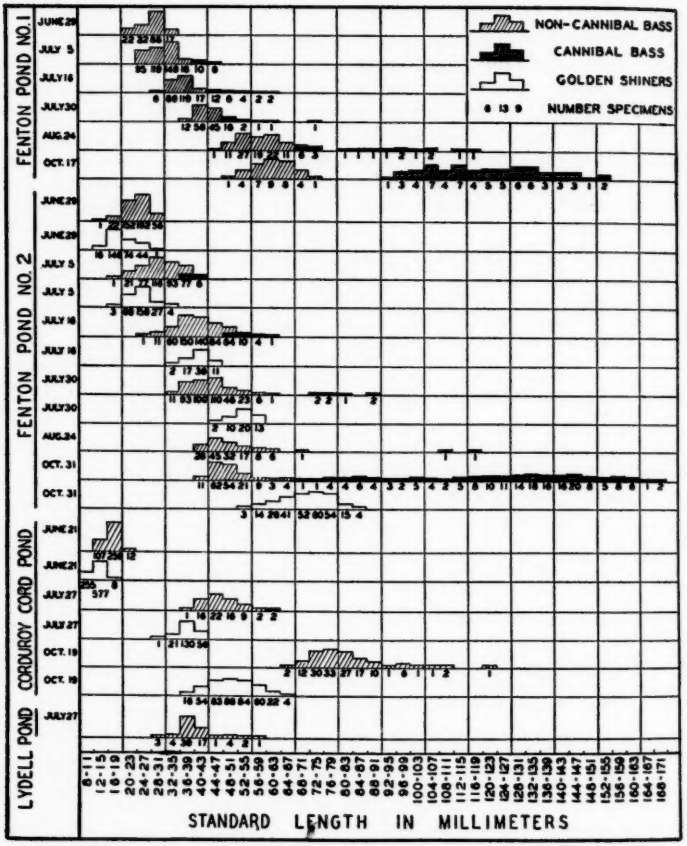


Fig. 1.—Length frequency distributions of young non-cannibal and cannibal largemouth bass and of young golden shiners in all collections from the four rearing ponds.

from each pond (Table 1). The amount of growth made by the bass in the two Fenton ponds prior to June 29 (date of the first sample) is not known. Those bass stocked in Pond 2 after June 29 (70,000 of the total 160,000 stock) were approximately the same average size as the bass already in the pond; therefore this introduction of bass into Pond 2 subsequent to the first sample was not an important cause for the difference in average size between the bass in the June 29 and July 5 samples. Data on production of bass in Corduroy Pond and on lengths and weights of bass in Lydell Pond at the end of the summer are not available.

The length frequencies of the bass and shiners in each collection are given in Figure 1. In the construction of Figure 1, the vertical dimensions of the graphs, in many instances, have been exaggerated at the extremes in order to show the presence of a relatively small number of specimens. The number of specimens, range in standard length, average length and average weight of all bass and shiners in each collection are given in Table 2. The rates of growth of all non-cannibal and cannibal bass in the four ponds are presented in terms of average standard length in millimeters in Figure 2; for this figure the data have been plotted on

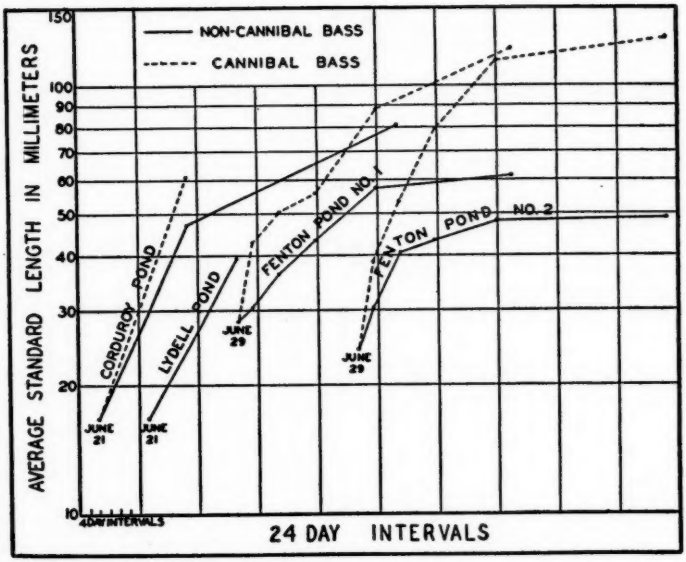


Fig. 2.—Average growth in length of non-cannibal and cannibal bass based on all collections from the four rearing ponds. Data are from Table 2 and are plotted on semi-logarithmic paper to show per cent of increase.

TABLE 2. NUMBER OF SPECIMENS, RANGE IN STANDARD LENGTH, AVERAGE LENGTH[1] AND AVERAGE WEIGHT OF ALL (EXCEPTIONS—SEE FOOTNOTES) NON-CANNIBAL AND CANNIBAL YOUNG LARGEMOUTH BASS (LMB) AND YOUNG GOLDEN SHINERS (GS) IN SAMPLES FROM FOUR BASS-REARING PONDS DURING 1935

	Locality	Fenton Pond No. 1						Corduroy Cord Pond						Eydell Pond
	Date	6/29	7/5	7/16	7/30	8/24	10/17	6/21		7/27		10/19		7/27
	Species	LMB	LMB	LMB	LMB	LMB	LMB	LMB	GS	LMB	GS	LMB	GS	LMB
Non-cannibal bass	No. specimens	159	381	232	127	93	34	375	..	67	..	143	..	71
	Range in length (mm.)	20–34	24–39	30–44	37–49	47–69	50–72	12–20	..	39–61	..	65–120	..	30–57
	Ave. length	28.1	30.4	36.1	43.2	57.4	61.5	16.7	..	47.2	..	80.4	..	39.3
	Ave. wt. grs.	0.57	0.7	1.1	1.9	4.2	5.2	0.11	..	2.8	..	12.2	..	1.5
Cannibal bass	No. specimens	..	16	25	9	18	64	..	..	1	..	..	..	..
	Range in length (mm.)	..	40–47	45–63	50–74	70–116	94–155	..	..	61	..	..	..	..
	Ave. length	..	42.7	50.1	55.6	88.4	121.7	..	..	61	..	..	..	..
	Ave. wt. grs.	..	2.2	3.1	4.4	17.0	41.6	..	..	7.5	..	..	..	..
Total	No. specimens	159	397	257	136	111	9,450[2]	375	840[2]	68	208	143	411[2]	71[4]
	Ave. length (mm.)	28.1	30.9	37.4	44.0	62.4	62.8	16.7	12.2	47.4	38.9	80.4	50.0	39.3
	Ave. wt. grs.	0.57	0.7	1.3	2.1	6.3	6.0	0.11	0.02	2.9	0.91	12.2	1.7	1.5

	Locality	Fenton Pond No. 2											
	Date	6/29		7/5		7/16		7/30		8/24	10/31		
	Species	LMB	GS	LMB	GS	LMB	GS	LMB	GS	LMB	LMB	GS	
Non-cannibal bass	No. specimens	423	..	365	..	504	..	390	..	137	164	..	
	Range in length (mm.)	15–30	..	19–40	..	27–50	..	33–61	..	40–68	41–66	..	
	Ave. length	24.2	..	30.4	..	40.6	..	43.4	..	48.2	49.0	..	
	Ave. wt. grs.	0.37	..	0.81	..	1.6	..	2.0	..	2.6	2.8	..	
Cannibal bass	No. specimens	..	..	26	..	21	..	7	..	2	184	..	
	Range in length (mm.)	..	..	38–41	..	51–61	..	74–88	..	108–119	71–171	..	
	Ave. length	..	..	38.7	..	53.5	..	79.6	..	113.5	128.6	..	
	Ave. wt. grs.	..	..	1.4	..	4.4	..	13.4	..	35.0	51.7	..	
Total	No. specimens	423	281[3]	391[3]	282	525	68	397	45	139	32,375[2]	271	
	Ave. length (mm.)	24.2	19.7	31.0	24.6	41.1	40.9	44.1	53.4	49.1	49.7	70.6	
	Ave. wt. grs.	0.37	0.14	0.85	0.26	1.7	1.3	2.2	2.9	3.1	3.3	5.7	

[1] All average lengths are based on the frequencies of single millimeter classes, not on the 4-millimeter classes listed in Figure 1.

[2] All collections were random samples of the pond populations except the October collections from the Fenton Ponds. At the time of draining in October, Fenton Pond No. 1 contained approximately 9,250 non-cannibal bass and 200 cannibals, and Fenton Pond No. 2 approximately 32,100 non-cannibal bass and 275 cannibals. Random samples (included in this table) of the non-cannibal and cannibal groups were taken separately for each group for each pond. The total average lengths and weights, however, are based on the entire populations of the two ponds.

[3] Only part of the entire sample is represented here. The June 21 collection from Corduroy Pond contained 1616 shiners; the October 19 collection from Corduroy Pond contained 1230 shiners; the June 29 collection from Fenton Pond No. 2 contained 621 shiners, and the July 5 collection from Fenton Pond No. 2 contained 741 bass. The specimens from these four collections which are listed in this table were taken at random from these total collections and are representative in size for the particular species and date.

a semi-logarithmic scale in order to show the percentage increase in length.

There was a considerable variation among the four bass populations in the amount of size dispersal which developed during the course of the summer. This size dispersal was much greater in the Fenton ponds than in the Corduroy and Lydell ponds. There was also a considerable variation in rate of growth. This was greatest in the Corduroy Pond and less in the Lydell Pond and Fenton ponds 1 and 2, in that order. The average rate of growth of the cannibal bass in the Fenton ponds was much greater than that of the non-cannibal population of any of the ponds.

When Fenton Pond 2 was drained in October, it was found to contain, in addition to the young bass, 16 bass ranging in total length from 9½ to 10¾ inches (see Figure 3). Examinations of scales from these larger individuals revealed that they were two summers old, or young of 1934. (These second-summer bass are not represented in any of the data presented elsewhere in this paper.) Whether they were introduced into the pond during late June as yearling fish along with the bass fry or whether they escaped from Pond 1 into Pond 2 during late fall in 1934 is not known. The scales indicated that these fish made a small amount of growth during 1934 (about the same as that made by the non-cannibal bass of Pond 2 during 1935, judging from the size of comparable growth areas of scales—Figure 4) but an enormous growth during 1935. Only circumstantial evidence is available to explain the exceptional second-year growth of these 16 bass in Pond 2. The only food supply available in any quantity was an almost unlimited supply of bass and shiner fry, and the supposition is that the yearling bass fed on these.

A group photograph of approximately average-size bass from several of the groups which have been discussed in this paper (the second-summer bass from Fenton Pond 2, the cannibal and non-cannibal young from Corduroy Pond) is presented in Figure 3. Photographs of scales taken from these same fish, and revealing their growth history, are shown in Figure 4.

Data on the numbers and lengths of non-cannibal bass from each collection which were examined for the present food studies are given in Table 3. A comparison of the data in Table 3 with that in Table 2 reveals that those bass which were studied were typical, in length range and average length, of their respective collections. A summary of the total number and total volume of each type of food organism taken from the non-cannibal bass of each collection is given in Table 4. The data on stomach contents of all bass studied are presented in Table 5 to show the variation in food habits according to size among each population of young bass at different times during the summer, and the variation in diet of each population throughout the summer. In the preparation of Table 5, the major food organisms were grouped into four

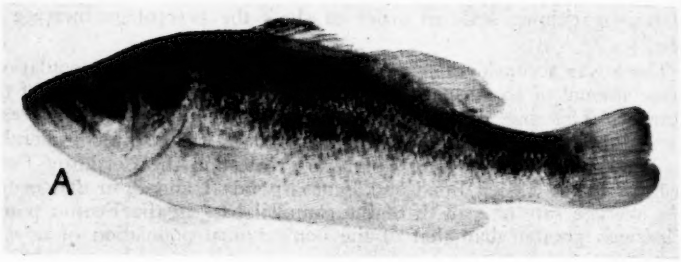
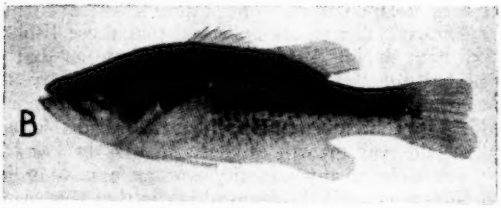
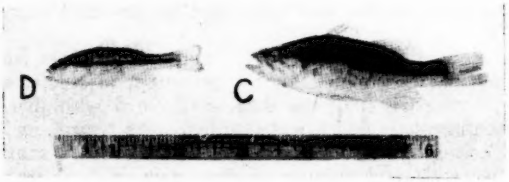


Fig. 3.—Group photographs of largemouth bass to illustrate variation in rate of growth. A scale from each fish is pictured in Figure 4.

A—Maturing male taken from Fenton Pond 2 on October 29, 1935 at the end of its second growing season. Standard length 227 mm., total length 268 mm., weight 332 grs. This fish was presumably a cannibal during its second summer, see scale in Figure 4.



B—Immature female cannibal taken from Pond 2 on October 31, 1935 at the end of its first growing season. Standard length 145 mm., total length 181 mm., weight 72 grs.



C—Immature female non-cannibal taken from Corduroy Pond on October 19, 1935 at the end of its first growing season. Standard length 77 mm., total length 96 mm., weight 10.3 grs.

D—Non-cannibal taken from Pond 2 on October 31, 1935 at the end of its first growing season. Standard length 52 mm., total length 64 mm., weight 2.4 grs.

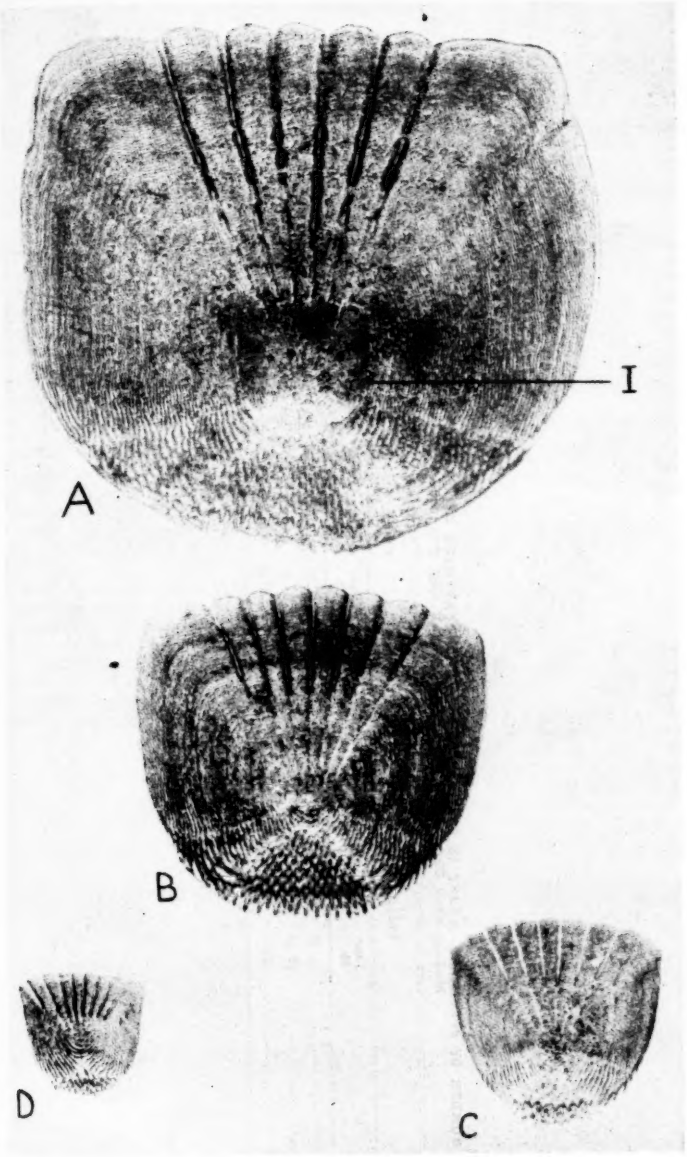


Fig. 4.—Scales from the bass shown in Figure 3 revealing their age and growth history. All scales are reproduced at the same magnification and are arranged in this figure in the order corresponding to that of the fish they represent. Data on the fish are given in Figure 3.

A—Fish two summers old (one annulus, I); cannibal during its second summer.

B—Cannibal young-of-the-year from Fenton Pond 2.

C—Non-cannibal young-of-the-year from Corduroy Pond.

D—Non-cannibal young-of-the-year from Fenton Pond 2.

TABLE 3. NUMBER OF SPECIMENS, RANGE IN STANDARD LENGTH AND AVERAGE LENGTH OF NON-CANNIBAL, YOUNG LARGEMOUTH BASS FROM EACH COLLECTION EXAMINED FOR FOOD HABITS

Locality	Fenton Pond No. 1					Fenton Pond No. 2				Corduroy Pond			Lydell Pond
Date	June 29	July 5	July 16	July 30	Aug. 24	June 29	July 5	July 16	July 30	Aug. 24	June 21	July 27	Oct. 19	July 27
No. specimens	41	47	49	43	42	118	53	65	55	44	50	67	143	71
Range in length (mm.)	22-33	29-37	30-41	38-49	48-69	16-30	19-40	31-50	35-57	41-68	13-20	39-61	65-120	30-57
Ave. length	28.4	31.2	35.7	43.4	58.3	24.4	31.9	39.9	44.5	49.8	17.3	47.2	80.4	39.3

TABLE 4. SUMMARY DATA FROM STUDIES OF STOMACH CONTENTS OF NON-CANNIBAL YOUNG LARGEMOUTH BASS COLLECTED DURING 1935 FROM FOUR PONDS, INCLUDING TOTAL NUMBER AND TOTAL VOLUME (IN CUBIC CENTIMETERS) OF EACH TYPE OF FOOD ORGANISM

	Fenton Pond No. 1									
	June 29		July 5		July 16		July 30		Aug. 24	
Food Organisms	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Cladocera	293	0.008	1032	0.015	803	0.025	8530	0.17	1332	0.10
Copepoda	114	0.01	1183	0.025	214	0.012	145	0.003	79	0.01
Ostracoda	14	tr.	71	tr.	32	0.003	5	tr.	8	tr.
Decapoda	...	....	1	tr.	...	....	...	....	...	....
Ephemeroptera, nymphs (Baetis and Caenis)	18	0.025	9	0.004	357	0.070	18	0.017	603	0.84
Zygoptera, nymphs and adults Coenagriidae	...	....	1	tr.	2	0.003	1	0.001	4	0.14
Anisoptera, nymphs										
Gomphidae (Gomphus)	...	....	...	....	1	0.002	1	0.005	...	....
Libellulidae	...	....	...	....	1	0.002	1	0.004	...	....
Homoptera	...	....	...	....	2	0.001	...	....	...	....
Hemiptera										
Corixidae	40	0.13	3	tr.	...	....	...	....	...	....
Other Hemiptera	...	....	...	....	3	0.002	...	....	...	....
Coleoptera, larvae										
Gyrinidae (Dineutes)	...	....	3	0.015	...	....	...	....	2	0.03
Hydrophilidae (Berosus)	...	....	6	0.024	7	0.04	14	0.10	4	0.05
Dytiscidae	13	0.005	6	0.025	...	....	...	....	...	....
Chironomidae, larvae	146	0.05	517	0.178	552	0.19	203	0.11	239	0.15
Diptera, adults	...	....	...	....	8	0.006	...	....	...	....
Hymenoptera	...	....	...	....	2	0.001	...	....	...	....
Aquatic insects (other)	2	0.002	5	0.004	8	0.013	...	....	1	tr.
Arachnida	...	....	...	....	2	tr.	...	....	...	....
Algae	...	....	...	....	...	....	...	....	?	tr.
Total volume	...	0.23	...	0.29	...	0.37	...	0.41	...	1.32

TABLE 4—Continued.

	Fenton Pond No. 2									
	June 29		July 5		July 16		July 30		Aug. 24	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Annelida										
Oligochaeta	...	....	...	....	2	0.11	...	....	...	....
Hirudinia	...	....	1	0.01	...	....	1	0.22	...	....
Cladocera	1288	0.06	6034	0.77	3206	0.10	3048	0.12	564	0.06
Copepoda	1690	0.13	553	0.06	3386	0.15	3009	0.16	183	0.02
Ostracoda	2	tr.	...	....	29	tr.	45	tr.	8	tr.
Amphipoda	1	tr.	...	....	...	....	...	....	...	....
Ephemeroptera, nymphs (Baetis and Caenis)	226	1.33	24	0.08	469	0.10	164	0.13	125	0.12
Zygoptera, nymphs and adults Coenagriidae	...	....	...	....	29	0.07	35	0.33	14	0.224
Anisoptera, nymphs Libellulidae	...	....	...	....	1	0.04	...	....	2	0.004
Homoptera	1	tr.	...	....	...	....	...	....	1	tr.
Hemiptera										
Corixidae	260	0.23	105	0.26	3	0.10	...	....	...	....
Gerridae	...	....	...	....	2	0.02	...	....	1	tr.
Coleoptera, larvae										
Hydrophilidae	...	....	...	....	...	....	1	0.002	1	0.002
Dytiscidae	18	0.02	19	0.05	10	0.01	5	0.008	2	0.004
Coleoptera, adults	...	....	...	....	5	0.04	1	tr.	1	tr.
Trichoptera, larvae										
Hydroptilidae	...	....	...	....	...	....	...	....	5	0.004
Limnephilidae	...	....	...	....	...	....	...	....	2	0.002
Chironomidae, larvae	175	0.13	174	0.39	374	0.13	219	0.17	62	0.07
Diptera, adults	...	....	...	....	6	tr.	1	tr.	1	tr.
Hymenoptera	...	....	...	....	...	....	...	....	3	tr.
Aquatic insects (other)	1	tr.	9	0.01	9	0.01	1	0.02	1	tr.
Terrestrial insects (other)	...	....	...	....	...	....	...	....	1	tr.
Arachnida	1	tr.	...	....	1	tr.	...	....	...	....
Animal remains	...	....	?	tr.	...	....	...	....	1	tr.
Algae	?	tr.	...	....	?	tr.	?	tr.	?	tr.
Undigestible debris	...	....	?	tr.	...	....	...	....	...	....
Total volume	...	1.9	...	1.63	...	0.88	...	1.16	...	0.51

TABLE 4.—Continued.

	Corduroy Pond June 21		Corduroy Pond July 27		Corduroy Pond Oct. 19		Lydell Pond July 27	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Annelida								
Oligochaeta	...	....	...	....	...	....	1	0.01
Hirudinia	...	....	2	0.203	1	0.01	2	0.10
Cladocera	408	0.06	2525	0.96	3512	2.4	1245	0.32
Copepoda	222	0.018	365	0.10	256	0.08	855	0.11
Ostracoda	...	....	36	0.002	2	tr.	75	0.01
Amphipoda	1	0.001	24	0.05	120	0.48	...	....
Decapoda	...	....	...	....	3	1.68	...	....
Ephemeroptera, nymphs (Baetis and Caenis)	8	0.005	725	3.12	4760	5.6	185	0.20
Zygoptera, nymphs and adults Coenagriidae	...	....	3	0.007	21	0.54	9	0.07
Anisoptera, nymphs								
Gomphidae (Gomphus)	...	....	3	0.007	...	....	...	....
Aeshnidae (Anax junius)	...	....	4	0.008	5	0.04	...	....
Libellulidae (Libellula)	...	....	...	....	71	0.54	...	....
Hemiptera								
Corixidae	1	0.001	12	0.018	5	0.10	...	....
Notonectidate (Notonecta)	...	....	...	....	3	0.05	...	....
Belostomatidae	...	....	...	....	...	....	1	0.007
Gerridae	...	....	...	....	...	....	3	0.003
Coleoptera, larvae								
Dytiscidae	2	0.001	15	0.03	...	....	6	0.015
Haliplidae	...	....	...	....	...	....	5	0.015
Coleoptera, adults	...	....	...	....	1	0.02	1	0.01
Trichoptera, larvae								
Hydroptilidae	...	....	...	....	...	....	7	0.013
Limnephilidae	...	....	...	....	...	....	6	0.012
Leptoceridae	...	....	...	....	...	....	2	0.005
Other Trichoptera larvae	...	....	...	....	1	0.02	...	....
Chironomidae, larvae	42	0.01	278	0.41	40	0.08	85	0.09
Diptera, adults	...	....	...	....	...	....	1	0.01
Aquatic insects (other)	...	....	25	0.044	?	0.08	?	0.22
Terrestrial insects (other)	...	....	...	....	...	....	10	0.03
Arachnida	...	....	...	....	1	0.10	...	....
Notemigonus	2	0.005	1	0.3	7	2.98	...	....
Animal remains	?	0.018	?	0.034	...	....	?	0.03
Algae	...	....	...	....	?	0.30	...	....
Plant remains	?	0.001	?	0.007	...	....	...	....
Undigestible debris	...	....	...	....	?	0.01	?	0.01
Total volume	...	0.12	...	5.3	...	15.65	...	1.3

classes according to size; several catagories of food organisms as listed in Table 4, such as "aquatic insects," "terrestrial insects," "animal remains" and "algae" were intentionally omitted in the preparation of Table 5. The non-cannibal bass in each sample were divided arbitrarily into two or three groups according to length; where cannibals were present, they constituted the third group.

The importance of each food class to each bass group of each collection was determined according to (1) the actual number and the per cent of stomachs containing each food class, (2) the total and average number of organisms of each class, (3) the average estimated per cent of food by volume for each class and (4) an "importance factor" obtained by multiplying the "per cent of stomachs containing each food class" by the corresponding "average estimated per cent of food by volume for each class." This "importance factor" is thus a weighted average and is believed to be the most significant index to the relative

TABLE 5. STOMACH CONTENTS OF 14 COLLECTIONS OF LARGEMOUTH BASS FROM FOUR PONDS AT DIFFERENT TIMES THROUGHOUT THE SUMMER OF 1935. ARRANGED ACCORDING TO SIZE GROUPINGS[1] OF BOTH BASS AND FOOD ORGANISMS. THE FOOD CLASSES INCLUDE THE FOLLOWING ORGANISMS:

FOOD CLASS 1 CLADOCERA, COPEPODA AND OSTRACODA
FOOD CLASS 2 EPHEMEROPTERA, DIPTERA LARVAE AND AMPHIPODA
FOOD CLASS 3 ODONATA, HEMIPTERA, COLEOPTERA, TRICHOPTERA, HOMOPTERA, DIPTERA ADULTS, HYMENOPTERA, ARACHINDA AND ANNELIDA
FOOD CLASS 4 DECAPODA, NOTEMIGONUS AND APLITES

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[2]	"Importance factor"
			FENTON POND NO. 1, JUNE 29			
			13 bass, 22-27 mm.			
1	11	85	360	33	25	21
2	10	77	76	7.6	69	53
3	5	38	14	2.8	18	7
			28 bass, 28-33 mm.			
1	8	29	61	7.6	9	3
2	16	57	88	5.5	52	30
3	11	39	39	3.6	81	32
			FENTON POND NO. 1, JULY 5			
			20 bass, 26-30 mm.			
1	18	90	1621	90	39	35
2	18	90	234	13	56	50
3	4	20	5	1.3	20	4
			27 bass, 31-37 mm.			
1	24	89	665	28	23	20
2	27	100	292	11	60	60
3	11	41	14	1.3	38	16
4	1	4	1	1.0	5	0.2
			16 cannibal bass, 40-47 mm.			
2	3	19	14	4.7	83	16
3	1	6	1	1.0	50	3
4	13	81	14	1.1	100	81
			FENTON POND NO. 1, JULY 16			
			23 bass, 30-35 mm.			
1	20	87	815	41	18	16
2	22	96	491	22	77	74
3	3	13	3	1.0	25	3
			26 bass, 36-41 mm.			
1	21	81	234	11	16	13
2	25	96	418	17	70	67
3	8	31	25	3.1	45	14
			25 cannibal bass, 45-63 mm.			
1	2	8	11	5.5	4	0.3
2	9	36	137	15	84	30
3	6	24	10	1.7	72	17
4	9	36	9	1.0	100	36
			FENTON POND NO. 1, JULY 30			
			23 bass, 38-43 mm.			
1	20	87	5923	296	73	64
2	13	57	55	4.2	24	14
3	4	17	5	1.3	56	10
			20 bass, 44-49 mm.			
1	16	80	2757	172	50	40
2	14	70	166	12	56	39
3	4	20	12	3.0	55	11
			9 cannibal bass, 50-74 mm.			
1	6	67	419	70	30	20
2	7	78	300	43	74	58
3	1	11	4	4.0	100	11

[1] The relative numbers of bass in the different size groups in most instances do not represent the components of random samples of pond populations for relatively large numbers of the cannibal class were selected for this food study. However, all bass not indicated as cannibals represent random samples of the non-cannibal populations.

[2] The average % by volume is based on only those specimens which contained the particular food class.

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[2]	"Importance factor"[1]
		FENTON POND NO. 1, AUGUST 24				
		22 bass, 48-58 mm.				
1	16	73	1215	76	21	15
2	18	82	339	19	79	65
3	2	9	2	1.0	24	2
		20 bass, 59-69 mm.				
1	15	75	204	14	12	9
2	18	90	503	28	76	68
3	6	30	8	1.3	41	12
		18 cannibal bass, 70-116 mm.				
1	8	44	111	14	4	2
2	14	78	574	41	60	47
3	11	61	37	3.4	54	33
4	3	17	3	1.0	86	15
		FENTON POND NO. 2, JUNE 29				
		48 bass, 16-23 mm.				
1	47	98	2314	49	34	33
2	42	87	167	4.0	56	49
3	36	75	127	3.5	24	18
		70 bass, 24-30 mm.				
1	57	81	666	12	12	10
2	68	97	235	3.5	79	77
3	51	73	153	3.0	19	14
		FENTON POND NO. 2, JULY 5				
		22 bass, 19-30 mm.				
1	22	100	3159	144	48	48
2	17	77	84	4.9	52	40
3	11	50	49	4.5	23	12
		31 bass, 31-40 mm.				
1	30	97	3428	114	55	53
2	16	52	114	7.1	45	23
3	20	65	76	3.8	31	20
		26 cannibal bass, 38-41 mm.				
1	5	19	127	25	8	2
2	12	46	47	3.9	36	17
3	15	58	65	4.3	63	37
4	9	35	9	1.0	98	34
		FENTON POND NO. 2, JULY 16				
		31 bass, 31-39 mm.				
1	27	87	3756	139	50	44
2	25	81	301	12	51	41
3	9	29	23	2.6	20	6
		34 bass, 40-50 mm.				
1	22	65	2865	130	39	25
2	25	74	542	22	42	31
3	15	44	36	2.4	66	29
		21 cannibal bass, 51-61 mm.				
1	4	19	28	7.0	2	0.4
2	12	57	187	16	70	40
3	10	48	16	1.6	54	26
4	7	33	7	1.0	92	30

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[2]	"Importance factor"[3]
		FENTON POND NO. 2, JULY 30				
		29 bass, 35-44 mm.				
1	29	100	4668	161	63	63
2	23	79	269	12	39	31
3	9	31	28	3.1	20	6
		26 bass, 45-57 mm.				
1	15	58	1434	96	54	31
2	17	65	114	6.7	53	34
3	5	19	16	3.2	79	15
		7 cannibal bass, 74-88 mm.				
2	1	14	2	2.0	60	8
3	2	29	6	3.0	28	8
4	3	43	3	1.0	95	41
		FENTON POND NO. 2, AUGUST 24				
		28 bass, 41-52 mm.				
1	24	86	659	27	37	32
2	22	79	151	6.9	54	43
3	8	29	11	1.4	49	14
		16 bass, 53-68 mm.				
1	8	50	96	12	38	19
2	11	69	36	3.3	23	16
3	10	63	23	2.3	75	47
		2 cannibal bass, 108-119 mm.				
3	1	50	2	2.0	25	13
4	1	50	1	1.0	75	38
		CORDUROY POND, JUNE 21				
		12 bass, 13-16 mm.				
1	12	100	148	12	75	75
2	4	33	11	2.8	15	5
3	1	8	1	1.0	20	2
		38 bass, 17-20 mm.				
1	35	92	482	14	73	67
2	15	39	40	2.7	30	12
3	2	5	2	1.0	10	0.5
4	2	5	2	1.0	95	5
		CORDUROY POND, JULY 27				
		41 bass, 39-48 mm.				
1	39	95	2341	60	22	21
2	41	100	616	15	72	72
3	11	27	18	1.6	16	4
		26 bass, 49-61 mm.				
1	25	96	585	23	14	13
2	25	96	411	16	77	74
3	8	31	21	2.6	24	7
4	1	4	1	1.0	60	2
		1 cannibal bass, 61 mm.				
4	1	100	1	1.0	100	100

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[2]	"Importance factor"
		CORDUROY POND, OCTOBER 19				
		50 bass, 65-76 mm.				
1	47	94	1769	38	24	23
3	18	36	36	2.0	25	9
2	49	98	1855	38	67	66
		82 bass, 77-92 mm.				
1	74	90	1787	24	27	24
2	80	98	2839	35	66	65
3	24	29	64	2.7	28	8
4	2	2	2	1.0	74	1
		11 bass, 96-120 mm.				
1	3	27	214	71	27	7
2	7	64	226	32	33	21
3	2	18	9	4.5	52	9
4	6	55	8	1.3	96	53
		LYDELL POND, JULY 27				
		26 bass, 30-37 mm.				
1	26	100	1462	56	54	54
2	21	81	102	4.9	37	30
3	5	19	12	2.4	50	10
		38 bass, 38-45 mm.				
1	34	89	713	21	33	29
2	26	68	173	6.7	51	35
3	12	32	27	2.3	35	11
		7 bass, 48-57 mm.				
3	3	43	5	1.7	52	22

importance of each food class, since it takes into account the frequency of occurrence of each and the relative importance of each to individual fish; it assumes, however, the total content of individual stomachs to be of equal importance regardless of the fact that the volumes of such contents may vary greatly with individual fish.

The great bulk of the food organisms found consistently in the stomachs of the non-cannibal bass from the four ponds throughout the season were micro-crustaceans, mayfly nymphs and chironomid larvae (Table 4). The larger aquatic insects (Odonata, Hemiptera, Coleoptera and Trichoptera) as a group were also important. The Amphipoda were of some importance only in Corduroy Pond. Terrestrial insects, arachnids, annelids, plant material and debris were generally of minor importance. The four food classes in sequence of importance to the four non-cannibal bass population as a whole, from greatest to least, were: 2, 1, 3 and 4 (Table 5). The cannibal bass had fed mostly on food class 4 (crayfish, bass and shiners).

Variations in Food Habits

The data presented in Table 5 reveal certain tendencies in food habits. The "importance factors" show, for the Fenton ponds, little or no defi-

nite trend towards a change in the importance of each of the first three food classes with the advance of the season; however, in Corduroy Pond, a big decrease in the micro-crustaceans was replaced chiefly by a big increase in the mayflies, chironomids and amphipods. Food class 4 was encountered to the least extent in the June samples, but the records of subsequent occurrence are too few to justify conclusions on the trend of importance of this food class during the remainder of the summer. Differences in food preference were consistent and prominent between the different size groups of bass of single collections. In almost every collection the smaller of the non-cannibal bass had fed more upon the micro-crustacea than had the larger ones. In general the two size groups of the non-cannibal bass of each collection had fed upon food class 2 (mayflies, chironomids and amphipods) in about equal amounts, and to a greater extent than had the bass of the cannibal group. Food class 3 (including the larger aquatic insects) was used more by the larger of the non-cannibal bass than by the smaller. Food class 4 was of importance only to the cannibal bass.

Relation of Volume of Food Contained to Rate of Growth

The data reveal that differences in average rate of growth between the bass populations are correlated with differences in the average volume of food contained in the stomachs. In enumerating the following comparative data, it is recognized that comparisons are significant only where the bass populations are of approximately the same average size or where smaller bass contain more food than the larger ones of another pond. The following comparison of non-cannibal populations are to be made:

1. June 29 bass of Pond 2 (ave. length 24.2 mm.) with June 29 bass of Pond 1 (ave. length 28.1 mm.).
2. July 5 bass of Pond 2 (30.4 mm.) with July 5 and July 16 bass of Pond 1 (30.4 and 36.1 mm.).
3. July 16 bass of Pond 2 (40.6 mm.) with July 30 bass of Pond 1 (43.2 mm.).

Whereas the bass in Pond 2 were smaller than the bass in Pond 1 on June 29, the average rate of growth of the Pond 2 fish during the period of June 29 to July 16 was much greater than the average rate of growth of the Pond 1 fish during the period of June 29 to July 30 (see Figure 2). The more rapidly growing fish in Pond 2 contained more food on the average. The average volumes of the stomach contents for each of the bass samples, just cited, are:

1. June 29 bass of Pond 2, 0.016 c. c.; June 29 bass of Pond 1, 0.006 c. c.
2. July 5 bass of Pond 2, 0.031 c. c.; July 5 and July 16 bass of Pond 1, 0.006 c. c. and 0.008 c. c. respectively.
3. July 16 bass of Pond 2, 0.014 c. c.; July 30 bass of Pond 1, 0.010 c. c.

This greater rate of growth of non-cannibal bass in Pond 2 during the early part of the summer was made in spite of a probably greater

concentration per acre. During essentially the same time period, Pond 1 was stocked with 15,600 fry per acre and yielded 2,950 per acre while Pond 2 received 25,000 per acre and yielded 5,060 per acre. During the latter part of the summer (July 30 to August 24 for Pond 1 fish, July 16 to August 24 for Pond 2 fish), however, the relative rates of growth of the bass populations in the two Fenton ponds was just the reverse of those during the first part of the summer—the Pond 1 fish grew more rapidly and made a much greater total growth. Here again the more rapidly growing fish contained the greater average volume of food (the August 24 fish of Pond 1 contained 0.031 c. c.; the July 30 and August 24 fish of Pond 2 contained 0.021 and 0.012 c. c.), but this fact is of doubtful significance because the Pond 1 fish were also the larger.

The much greater rate of growth of bass in Corduroy Pond over the two Fenton ponds was definitely correlated with the amount of food eaten. The July 27 bass from Corduroy contained an average of 0.079 c. c. or approximately 2½ to 7 times the amount contained by the bass in the August collections from the Fenton ponds (the bass in the latter were the larger). The amount contained by the October bass from Corduroy was also comparatively very great (ave., 0.109 c. c.), but its significance is open to question due to lack of comparative material. According to the estimates by members of the Lydell Hatchery staff, the Corduroy Pond contained in excess of 13,000 young bass per acre at the beginning of the summer, or at least nearly the equivalent of the initial stocking of Fenton Pond 1. The data suggest that the greater total increase in length, during the summer, of the bass in Fenton Pond 1 over that of the bass in Pond 2 was, at least in part, due to the fact that there were fewer fish per acre in Pond 1, but that the big difference in rate of growth between the Corduroy and Fenton Pond 1 bass was due chiefly to differences in amount of food consumed. General observations at the time of sampling indicated that Corduroy Pond was, by far, the richest of the three ponds in abundance of food organisms, especially the mayflies.

Relation of Food Habits to Size Dispersal and the Beginning of Cannibalism

The data obtained during the present food studies suggest that food is a factor of prime importance in the increase of size dispersal. It has been indicated that the larger of the non-cannibal bass fed upon food class 3 (the larger aquatic insects) more than did the smaller ones, and conversely, the smaller ones fed on food class 1 (micro-crustacea) more than did the larger ones. Further, it was observed during the food studies that the actual volume of the contents of individual stomachs was much greater when the food was mostly insects than when it was mostly micro-crustaceans. This fact is suggested by a comparison of the "importance factors" (Table 5) with the data on measured volume

of food organisms (Table 4); the aquatic insects are ranked as more important by the measured volumes than by the "importance factors" which do not take into account the variation in volume of the contents of individual stomachs. The fact that, over a considerable portion of the summer, the larger of the non-cannibal bass actually fed upon food class 3 (the aquatic insects) more than did the smaller of the non-cannibal group is indicated by the data, for example: among the bass of Fenton Pond 1 (comparing fish of the same size) the "importance factor" of food class 3 for the larger of the non-cannibals of June 29 was 32, while that for the smaller of the non-cannibals on July 16 was 3, the two groups being of the same size range, approximately, on their respective dates—all similar comparisons for the Fenton ponds reveal the same circumstance. The food organisms of food class 3 of most importance to the bass in the Fenton ponds during the early part of the summer were the Corixidae and Coleoptera, and during the early summer the supply of corixids was nearly exhausted. During the latter part of the summer the larger insects of food class 3, such as the Odonata, replaced the corixids. It is believed that the unequal extent of utilization of the larger aquatic insects was responsible for the initiation of the rapid increase in size dispersal among the Fenton bass during the summer. During early summer the larger bass, by virtue of their size advantage, fed more upon the corixids than did the smaller bass, and nearly eliminated these insects before the smaller bass reached a sufficient size to use this food source to an equal advantage. The resultant size dispersal was sufficient to allow cannibalism to begin.

This explanation of the beginning of cannibalism receives confirmation from a comparison of the conditions in the Fenton ponds with those of Corduroy Pond. In Corduroy, the larger aquatic insects were of less importance; the entire population was more uniform in food habits at any one time; there was much less size dispersal among the bass, and the occurrence of cannibalism was less frequent in Corduroy Pond (0.47% among all specimens collected) than in Fenton ponds 1 and 2 (2.1% and 0.8% respectively at the time the ponds were drained in October; 7.5% and 3.9% in the summer collections).

Relation of Cannibalism and Volume of Food Contained to Size Dispersal

Once cannibalism was started, by virtue of a certain size advantage of predator over prey the cannibals continued to grow much more rapidly than the non-cannibals, resulting in a continual increase in size dispersal throughout the summer. This continual increase in size dispersal may have been a necessary condition for the continuation of cannibalism as well as the result of it. The average difference in length between predator and prey in the Fenton ponds increased continually, from 16.9 mm. on July 5 to 21.2 mm. on July 16 to 46.5 mm. on July

30 to 56.5 mm. on August 24 (Table 6). The data indicate that cannibalism was dependent upon size dispersal and that (comparing the Corduroy population with those of the Fenton ponds, see Figure 1) the amount of cannibalism was proportional to the extent of the size dispersal.

The much greater rate of growth of cannibal over non-cannibal bass was unquestionably due to the fact that they consumed a much greater amount of food which was probably also of more nourishing quality. The total content of the stomachs of the 557 non-cannibal bass from the Fenton ponds listed in Table 5 was 8.70 c. c., an average of 0.016 c. c. per stomach. The total content of the stomachs of the 124 cannibal bass from the Fenton ponds listed in Table 5 was 21.91 c. c., an average of 0.17 c. c. per stomach or 10 times that for the average non-cannibal bass; 17.09 c. c. or 78% of this amount consisted of food class 4 (bass, shiners and crayfish), and the remainder was mostly the larger aquatic

BLE 6. RANGE IN STANDARD LENGTH (MM.) OF CANNIBAL BASS AND OF BASS FOUND IN HEIR STOMACHS AND AVERAGE DIFFERENCE IN LENGTH BETWEEN PREDATOR AND PREY

ality	Fenton Pond No. 1			Fenton Pond No. 2				Corduroy Pond
e	July 5	July 16	Aug. 24	July 5	July 16	July 30	Aug. 24	July 27
gth: cannibals	40-47	45-63	70-116	38-41	51-61	74-88	108-119	61
: cannibals	16	25	18	26	21	7	2	1
gth: bass eaten	24-30	31-38	49	22-24	30-36	35-36	45	39
: bass eaten	14	7	1	8	6	2	1	1
e difference in length: predator and prey	17.1	20.9	50	16.6	21.5	46.5	63	22

insects. Also, the cannibal bass contained more food than did non-cannibals of the same size, or larger, taken at a later date. Of the Fenton Pond 1 collections, the 16 cannibals of July 5 contained an average of 0.201 c. c. while the 43 non-cannibals of July 30 contained an average of 0.010 c. c.; the 25 cannibals of July 16 and the 9 cannibals of July 30 contained 0.143 and 0.084 c. c. respectively, while the 42 non-cannibals of August 24 contained 0.031 c. c. Of the Fenton Pond 2 collections, the 26 cannibals of July 5 contained an average of 0.057 c. c., while the 65 non-cannibals of July 16 contained 0.014 c. c. The 21 cannibals of July 16 from Pond 2 contained an average of 0.285 c. c., whereas the 42 non-cannibals of August 24 from Pond 1 contained an average of 0.031 c. c. The bass population of Corduroy Pond was about intermediate between the cannibals and the non-cannibals of the Fenton ponds in average rate of growth (Figure 2) and in average volume of

stomach contents. The data obtained point to the conclusion that for all bass, cannibal or non-cannibal, the rate of growth was approximately in proportion to the amount of food contained in the stomachs.

The presence of the 16 second-summer bass in Pond 2 offers further evidence of the inherent capacity of the largemouth bass for rapid growth if sufficient food is available. The apparently reliable circumstantial evidence points to the conclusion that the enormous amount of growth during their second summer was the result of an almost unlimited food supply; their very slow growth during the first year was probably due to a limited food supply.

Relation of Average Growth of the Population to Amount of Cannibalism

Those factors which were found to be conducive to cannibalism—unequal utilization of certain types of food, and the resultant increase in size dispersal—were of less importance, and consequently the frequency of cannibalism was less, among the more rapidly growing population of bass in Corduroy than among the more slowly growing populations of the Fenton ponds. Thus it appears that the rate of growth of the bass populations was another factor of importance in the development of cannibalism.

Golden Shiners as Forage in Bass Ponds

The present study has furnished some information on the problems involved in the use of golden shiners as a forage in bass rearing ponds. In Fenton Pond 2, young shiners, according to the collections and counts made at the time the pond was drained, outnumbered the bass two to one at the beginning of the summer, but by the end of the season the proportion was about one to one. Young shiners in Corduroy outnumbered the young bass more than five to one, and were several times as abundant as the shiners in the Fenton Pond. The rate of growth of the shiners was more rapid in Pond 2 than in Corduroy (just the opposite of that of the bass in the two ponds, see Figure 1), and was correlated with density of population. Shiners were found in bass stomachs in two instances for the Fenton Pond (July 16 and 30) and in ten instances for Corduroy Pond (June 21 to October 19). It does not follow, however, that the Corduroy bass ate more shiners solely because the shiners in this pond were smaller, for they were also at least five times as abundant. In the Fenton Pond the bass involved were of the cannibal class; the differences in length between bass and shiner were 13 to 38 mm., respectively. For Corduroy the bass were also among the largest of the population and the shiners were among the smallest; the average differences in length between the bass and the shiners which they ate were 9 mm. for June 21, 21 mm. for July 27 and 63 mm. for October 19—a continual increase in the difference in length between predator and prey.

The data reveal that size of the fish-prey was the most important factor in determining whether the larger bass fed on the smaller bass or on the shiners. From Fenton Pond 1 there were seventeen recorded instances of cannibalism and two instances of predation on shiners; from Corduroy there were ten instances of predation on shiners and one instance of cannibalism. In the former pond the smallest of the shiners were larger than the smallest of the bass; in the latter pond the reverse was true. A greater difference in size frequency between the populations of bass and forage minnows than existed among the fishes in Corduroy Pond is necessary for an extensive use of the shiners as food by the bass.

Discussions

Dr. Huntsman: I should be interested to know to what extent you have been able to distinguish cause from effect in this case. Were the larger fish large because they were cannibals, or were they cannibals because they were large?

Mr. Cooper: It is a vicious circle. There is a certain amount of size dispersal necessary to cannibalism, but of course after you get the cannibalism started the amount of size dispersal increases.

A Delegate: To what extent did the golden shiner take the bass?

Mr. Cooper: I do not believe they take them at all.

Mr. Hansen: Do you conclude that the golden shiner is not a good forage fish?

Mr. Cooper: I would not say that at all. The whole point is that in order to have the shiner population of a size which the bass can eat, the shiners have to be somewhat smaller than the bass. Ordinarily shiners will spawn about the same time as the bass, and only the larger of the bass will be able to eat the shiners, and then only the smallest of the shiners. Where a hatchery has a cold water supply available, they could hold the brood stock of shiners over in this until about the end of June and then put them into their bass ponds. By this means spawning can be delayed until the first of July or possibly later.

A Delegate: You would put the adult shiners into the bass ponds?

Mr. Cooper: I would hold the adult shiners in cold water, if it is available, in order to retard the spawning season, and then put them in the bass pond after the bass have reached the desired size.

A Delegate: Then wouldn't the adult shiners take the young bass?

Mr. Cooper: Not over an inch long, I am sure. I have carried out a few experiments on that which I reported on last year, and which indicated that large golden shiners, seven to eight inches long, eat young bass up to about three-quarters of an inch long but not longer.

Mr. Langlois: I was interested in Mr. Cooper's statement that the difference in the rate of growth is based on the fact that the bass which had eaten golden shiners had eaten more food than the ones which had eaten insects. It is my impression that bass will grow more rapidly on a diet of fish than on a diet of insects, regardless of whether they eat the same amount or not.

Mr. Cooper: I think that is true. In a collection of fifty bass I examined, if I had one cannibal with one bass in a stomach it would have a greater volume than all the stomach contents of the other forty-nine bass, so that the comparison was really very striking.

Mr. Langlois: Did you analyze the population when the pond was drained?

Mr. Cooper: In two of the ponds.

Mr. Langlois: Did you find distinct size groups of predators at the time the pond was drained?

Mr. Cooper: Yes.

MR. LANGLOIS: If the pond is allowed to run long enough, the prey is eliminated completely.

MR. COOPER: Of course if it had been run long enough to eliminate the prey, the production would have been nothing.

MR. LANGLOIS: The usual practice among bass culturists raising fish in that way is to drain the ponds as early in the season as possible in order to get out the maximum number.

MR. O. R. KINGSBURY (New York): I would like to make one or two comments on holding back golden shiners in spring ponds. Last year we had two thousand golden shiners; we had some of them spawn in May, and by putting the remainder in a spring fed pond we were able to have them spawn on the fifteenth of August. This year we held back shiners and goldfish in cold water, and by putting them into a shallow pond with willow root screens or rope mat on the bottom, the fish would spawn on the rope mat or the willowroots; we would set that over in the pond and in that way we did not have any adult forage fish in the pond. The great trouble is getting them over at the right time. Apparently the minnows grow a lot faster than the fish you want to raise.

FOES ENCOUNTERED IN THE REARING OF SMALL-MOUTH BASS

OLIVER R. KINGSBURY

New York State Conservation Department, South Otselic, N. Y.

The loss of fish in rearing ponds may be attributed to at least four general causes, namely, predatory aquatic insects and insect larvae, predatory vertebrates, excessive vegetation, and diseases. In this paper I wish to report on the losses of fish in the rearing ponds at South Otselic, New York, due to these four causes, and on the methods used in combating this destruction of fingerlings.

One of the worst enemies of fingerlings among the aquatic insects is the back-swimmer of the genus *Notonecta.* This insect increases rapidly in numbers in a pond which has a good food supply, so that its presence is a serious menace to such food of the small fish as *Daphnia,* and even to the fish themselves. The body of the insect is boat-shaped. Back-swimmers swim with their hind legs but have the ventral side of the body upper-most, except when they are about to take flight. They come to the surface for air which is carried in a space beneath the wings. The beak is sharp and capable of inflicting a painful sting. During the winter back-swimmers hibernate in the mud.

It is an easy matter to control back-swimmers in fish ponds. If oil is sprayed on the surface of the water these insects can not penetrate the surface film to obtain air. A single oil treatment destroys the insects but does not harm the eggs which they have deposited in the pond. Therefore, it is necessary to repeat the oil treatment at intervals to destroy the new hatches of back-swimmers. One part of cod liver oil mixed with three parts of gasoline is used as a spray at the South Otselic hatchery with very good results. The ponds should be sprayed on a warm still day so that the oil film will cover the entire surface of the pond. Dr. Langlois (1932) mentioned the use of coal oil as a means of control but stated that the *Daphnia* were killed as well as the back-swimmers.

Water-beetle larvae also cause great loss among the fish of a pond. The small larvae compete directly with the fry for the natural food supply of the pond, and as the larvae become larger some species feed upon the fish. The larvae of *Dytiscus, Cybister,* and *Hydrous* are known to eat small fish as a part of their regular diet (Wilson 1923). The form that has caused trouble in our ponds belongs to the genus *Dytiscus,* commonly called the water-tiger.

The adult female water-tigers deposit their eggs at random in the water. The larvae are slender and spindle-shaped. The head is relatively large and flattened. The mandibles are comparatively large, sickle-shaped, and hollow with a slit-like opening near the tips. The

mandibles are exceptionally well fitted for holding prey and at the same time sucking the juices from it, the hollow of the mandibles communicating with the esophagus. The true mouth is relatively small. Only liquids are ingested by the mandibles. The thorax has six legs. The abdomen ends in a pair of breathing tubes which are protruded above the surface of the water at intervals for air. When the larvae is fully grown it leaves the water, burrows into the ground, and makes a round cell within which it undergoes its transformation. The pupal stage lasts about three weeks in summer but the larvae that transform in autumn remain in this stage during the winter.

These predacious water-tigers can be controlled in rearing ponds by spraying oil on the surface as in the case of the back-swimmers.

In order to determine the advisability of spraying ponds, all of our rearing ponds were treated at intervals last season with the exception of one pond which served as a control. The sprayed ponds had oniy a very few small larvae in them whereas the control pond had a large population of larvae of various sizes. It was observed that the larvae began their attacks in this pond when the fish were about one and one-half inches long. The water-tiger would hang suspended head downward until a fish came within striking distance when by a rapid movement the larva would grasp its victim near the tail. In a very short time the mandibles would grasp the fish on the ventral side of the body near the head. After the juices were sucked out of the fish the larva would leave its victim and rise to the surface for air. On close examination of the fish the only injuries found were the mandible marks where the juices had been extracted.

When the control pond was drained it was found that thirty-three per cent of the fish had survived whereas in the sprayed ponds there was on the average a survival of sixty-six and one-half per cent. As all factors which might influence the production in the ponds were believed to be the same except for the presence of the *Dytiscus* larvae in the control pond, it would seem that the larvae were entirely responsible for the large decrease in production.

A predator that equals the water-tiger in destructiveness is the nymph of the dragonfly. It apparently does not prey on fish until they exceed an inch in length. An explanation of this might be that the nymphs and the fish have exhausted the available food supply in the pond and as the nymphs are larger than the fish they take them as the only remaining source of food.

This season many nymphs of the species, *Anax junius*, were present in three of our rearing ponds in spite of the fact that they had been drained last autumn leaving them exposed to the action of frost and sunlight. This spring each pond was harrowed twice and smoothed but not sterilized. For stocking these ponds *Daphnia* were netted from propagating ponds that had not been sterilized. Three possible sources of the nymphs in the ponds are therefore: (1) the survivors of the

treatment given the ponds; (2) the water supply; (3) the accidental introduction with the *Daphnia* culture. The number one rearing pond yielded from one to five nymphs to each square foot of bottom area.

Artificial feeding of the fish was started in pond number one on the twenty-ninth of June. Conditions apparently were normal in the pond until the fourth of July when the visible mortality increased to twenty-eight fish per day. Most of these fish had the stomachs eaten out which is a sign that the dragonfly nymphs had been at work. Each day the visible mortality grew greater until the eleventh of July when seventy-eight dead fish were removed from the pond, all showing evidence of having been attacked by nymphs. During this entire period there had apparently been a struggle between the fish and the nymphs for supremacy of the pond and the latter were winning the battle. The pond was drained on the twelfth of July yielding nine and six-tenths per cent of the fry originally stocked.

Another rearing pond stocked with approximately the same number of fish as was introduced into pond number one yielded seventy-five per cent of the stocked fish. This pond had only a very few *Anax* nymphs in it, otherwise the conditions were like those of pond number one. It would appear from this that a large invasion of *Anax* nymphs in a pond is capable of cutting the production of a rearing pond at least fifty per cent.

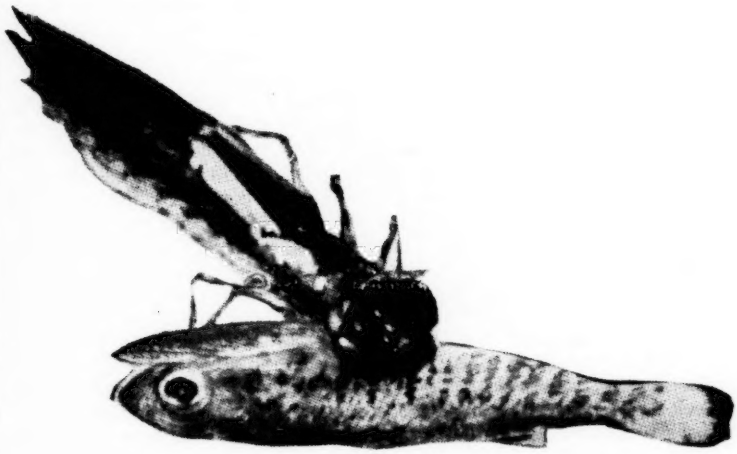


Fig. 1.—Dragonfly Nymph Attacking Smallmouth Bass.

Many attacks by *Anax* nymphs on fish were observed (Fig. 1). The nymphs lay in wait clinging to vegetation or resting on the bottom but

never moving. In one instance a nymph of the species, *Anax junius,* was resting on the bottom while a small fish nearby was worrying a tadpole each time it moved. The fish finally came within an inch or so of the waiting nymph which immediately threw out its labium, expelled water from the abdomen, and seized the fish between its dorsal fin and the tail. While the nymph was endeavoring to change its hold so as to be in a position to eat the soft stomach tissue, three other little bass seeing the battle came over and from time to time would dart in striking at the fins of the captured fish but never at the nymph. When the nymph finally had maneuvered to a proper position for its meal, three minutes having elapsed from the time of capture, a stick was poked down which interrupted the struggle. The nymph released its hold and the fish swam away apparently uninjured.

The adult female of *Anax junius,* after mating, lays its eggs in the soft tissue of water plants or water trash. The ovipositor is adapted for cutting holes in aquatic plants. Close inspection of a stem where eggs have been deposited will reveal a perfect double row of punctures through which the eggs have been inserted. The development of the egg and the hatching of the nymph require about three weeks. The nymph moults from time to time to permit growth. After the third or fourth moult the wing covers appear and increase in size with each successive moult until maturity. When it is time for the nymph to transform, approximately eleven months after the deposition of the egg, it crawls up the debris or vegetation to the surface of the water where it is exposed to the air. Then the nymphal skin splits behind the head and the adult emerges. It rests an hour or so while the wings dry and the body becomes rigid before it flies away.

Dragonfly nymphs can be exterminated in a rearing pond only by sterilizing it in the late fall or early spring. This treatment will kill the nymphs of the preceding season which are the ones that prey upon the fish. Whatever method of control is practiced to keep these nymphs out of the rearing pond, one should inspect constantly the dead fish during the production season for signs of the presence of dragonfly nymphs. By such inspection one may determine when it is necessary to remove the fish and save the production.

Cannibalism can be a serious factor in reducing the production of bass fingerlings. Only the larger bass show cannibalistic tendencies. When cannibalism occurs, it is necessary to drain the pond and grade the fish according to size. Generally we find it advisable to do this after the fish have been feeding on artificial food for from one to three weeks. Usually three size-groups are present. Each of these groups is segregated. We find that artificial food is taken readily if there is no other food available for the young bass.

Three species of fish that will cause a marked decrease in the survival of bass in a rearing pond are pickerel, pike, and muskalonge. Small fry of these species are likely to get into the pond through the

water supply when the ponds are filled. Two seasons ago we had two one-half acre ponds stocked with the same number of fish. These ponds showed the same food and mortality records up to the end of the first week of artificial feeding of the bass. Then the amount of food consumed by the fish in one of the ponds decreased, and there did not appear to be as many fish present as in the other pond. Both ponds were drained after the fish had been fed for three weeks, and it was found that the pond that had 2,000 less bass in it than the other also contained one seven-inch pickerel. At our Ogdensburg, Oneida, and Bemus Point hatcheries the presence in a bass rearing pond of one or more of any one of the three species of fish mentioned above has been believed to be sufficient cause for any marked decrease in the yield of bass fingerlings.

Bullfrogs sometimes cause trouble in ponds if food other than the young bass is not present. One bullfrog stomach, examined in 1933, yielded 123 bass fry. Other stomachs contained as many as three three-inch fingerlings. Two stomachs from bullfrogs captured in the outlet ditch had five-inch trout in them. However, I believe that these two cases are uncommon. Out of eighteen bullfrog stomachs examined this season only one contained bass fry and that one had only four fry. Many of these stomachs were empty although plenty of young bass were present in the ponds where the frogs had been captured.

Turtles and fish-eating birds such as the kingfisher, great blue heron, and green heron take their toll from rearing ponds. These predators do not cause trouble until the fish have reached an advanced fingerling stage. The kingfisher is not a menace unless there are trees near the ponds from which it can fish. The great blue heron has to wade in the water to fish, therefore, as a general rule, it does not operate in water which is deeper than the length of its legs. One great blue heron was allowed to fish in one of our rearing ponds for an hour last season. Its stomach was examined afterwards and seventy-three bass that averaged two and one-half inches in length were removed.

Vegetation very often threatens the life of the fish in a pond. There are localities in the United States where vegetation is necessary in ponds since it serves to reduce the high water temperatures. In the Northern States, however, the water rarely ever becomes too warm for bass fingerlings. Last season one pond at the South Otselic hatchery had a growth of *Potamogeton pectinatus* on the bottom. The water temperature in this vegetation was 10°F lower than that at the surface. The fish that inhabited this area did not feed well but when the pond was cleaned and the fish returned to it all fed uniformly.

Alga is a serious menace in a pond when it becomes overabundant. *Hydrodictyon,* the net alga, causes trouble during the early part of the season. This year pond number five had a luxuriant growth of net algae when the fish were about three-fourths of an inch long. Careful inspection revealed many little fish gilled in the net algae. One cyl-

indrical piece of this algal growth about ten inches long had five small bass enmeshed. All of these fish were dead and all had perfect gill-net marks at the base of their gill covers. Later in the season *Cladophora,* another type of algae, is likely to hinder artificial feeding.

It is very difficult to control the growth of vegetation in fish ponds when the fish are present. The introduction of copper sulphate is the method of control commonly used. This method is dangerous because the lethal dosage for the type of vegetation one wishes to control is likely to be near that for the fish. Then again if the lethal dosages of the two do differ enough to make the use of copper sulphate safe, the plant growth, while decomposing, is likely to reduce the oxygen in a pond to the danger point. We use copper sulphate in large ponds only after the fish have first been removed. When vegetation of any type becomes troublesome at our hatchery, the pond is drained, the fish removed, and the pond cleaned. It is sterilized with copper sulphate before it is used again.

Diseases can reduce greatly the production in a bass hatchery if they are not checked when they appear. *Ichthyophthirius* generally appears at the South Otselic hatchery on the smaller sized fish after the *Daphnia* supply has been exhausted. By removing the fish from the pond and treating them with a three per cent salt bath three times, allowing one day between treatments, this disease can be controlled.

Ancyrocephalus, which occurs on the gills, resembles *Dactylogyrus* in appearance in that it has four eye spots. *Dactylogyrus,* however, has two large middle hooks in the fastening disc whereas *Ancyrocephalus* has four. *Ancyrocephalus* is easily controlled with potassium permanganate. In troughs the fish will stand a concentration of 1: 50,000 of potassium permanganate for thirty minutes with the water supply shut off. This treatment is very effective and does not injure the bass. When either *Ichthyophthirius* or *Ancyrocephalus* is found on the fish, one is apt to find *Cyclochaete* and a stentor-like protozoon associated with the infection. The permanganate or salt bath will control both of these forms.

During the past two seasons we have had tailrot occur on bass in some ponds soon after artificial feeding was started. This disease seemed to have been caused by the overfertilization of the rearing ponds. To check this disease the bass were removed from the pond, given a permanganate bath of 1: 50,000 for thirty minutes, and then returned to a clean pond.

Another disease with which we have had to contend for the past two seasons is a bacterial infection. It manifests itself by whitish patches, which look like bruised areas, on the sides of the body of the bass and on the head. When the disease becomes more advanced the affected areas are covered with fungus. The ventral side of the head shows blood congested spots while the snout is white and covered with fungus. The fish act sluggish and swim near the surface of the water.

A three per cent salt bath followed by a permanganate bath of 1: 50,000 for thirty minutes checks the disease.

If any of these diseases occur in the fish of a pond and are allowed to run their course unchecked the loss of fish is great. In 1933 there was an outbreak of *ichthyophthirius* among the fish in two of our ponds. The disease was allowed to run its course and as a result one of the ponds yielded only three per cent of the stocked fish, the other only six per cent.

In controlling these diseases the diet is an important factor. If one can get infected bass to eat well they will soon throw off the disease. On the other hand, chemical treatments are of no avail unless the fish are well nourished. Most of the serious infections occur at the time when the small fish are learning to take artificial food. If this feeding is started in advance of the time when the natural food supply is exhausted it aids in preventing the occurrence of diseases.

A few years ago forty per cent survival in bass rearing ponds was considered a good harvest. In more recent years, with the advent of artificial feeding, an increase in this survival has been attained. In our ponds last year we raised 24,380 two and one-half inch fingerlings to the acre of water. The highest survival we have procured from a pond, from the fry to the fingerling stage, is 83.2 per cent. If the time comes when we can more readily control the causes that destroy the small bass in rearing ponds we may expect this high survival in all ponds.

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FURTHER OBSERVATIONS ON HABITS OF THE CRAYFISH, *CAMBARUS RUSTICUS* GIRARD

T. H. Langlois

Chief, Bureau of Fish Management and Propagation, Ohio, Division of Conservation, Columbus, Ohio

The observations presented herewith are intended to supplement those offered in the Transactions of the American Fisheries Society for 1935.

Although the principal egg-laying period of the crayfish, *Cambarus rusticus*, is the spring, a few females are found with eggs attached to their swimmerets in the fall. Only one pond of the series at Ohio State fish farm No. 1 yielded females with eggs when the pond was drained on October 25, 1935, and forty females in this condition were obtained. These females were placed in a bucket with only about three inches of water in it, and allowed to freeze with the water on December 21. After being encased in ice for twenty-four hours they were thawed out gradually, and of the forty, twenty-five were still alive and active. Subsequently these twenty-five were frozen in for seven days but none survived this treatment. Under normal conditions these fall eggs apparently hatch in early March, for one female was found with young attached to her swimmerets on March 14, 1936, at the Ohio State fish farm No. 4.

In the early spring the males remain on the pond bottoms where they may be seen feeding vigorously by day and night, while the females seek individual sheltering pockets under stones. Oviposition occurs earlier in the year in the southern part of Ohio than farther north, and is therefore apparently controlled by temperature conditions. At Ohio State fish farm No. 2 none of the 128 females examined were found with eggs on February 24, 1936. The first visible eggs were found March 13, and seventy-nine out of ninety-eight females bore eggs on March 21. Ninety miles northward, at Piqua, the first females were found with extruded eggs on March 16, 1936, and on April 23, twenty-four out of twenty-nine females bore eggs. At Chagrin Falls, in the coldest zone of the state, no females were found with eggs until April 11, when eleven very large females bore eggs while 114 did not. This latter observation is the only indication that there may be a difference in the time of oviposition among females of different size and age groups.

The exact incubation period has not yet been determined. At Ohio State fish farm No. 6 every stone raised from the bottom of pond No. 9 on May 14, 1936, yielded a female with eggs which were closely approaching the hatching stage, and on May 26, all females were free of their young which were seen in abundance around every rock pile. On May 27, young crayfish were seen on the shoals of ponds at Ohio State fish farms Nos. 2 ,4, 7, 8, and 9.

Young crayfish which shook loose from a female on May 15 averaged six millimeters in length. Young collected from a pond on June 8, averaged 17.5 millimeters in length; on June 21, twenty-nine millimeters; on July 14, thirty-six millimeters; and on August 18, forty-three millimeters. On October 30, 1935, the young of the year averaged sixty millimeters in length at Defiance, while those reared in the colder water at Chagrin Falls averaged only fifty-two millimeters.

Discussion

Mr. E. R. Hewitt (New York): Do you know whether the French crayfish has been introduced into this country? It runs about four and a half to six or eight inches in length, and is a considerable item of food in northern and eastern France.

Dr. Langlois: No, I do not know. Do you know, Commissioner Bell?

The President: No.

Mr. Hewitt: It is a valuable item of food, and I think we ought to have it in this country in places where it is suitable. They are sold on the dock at Cologne every day, and any steamer could bring them over by the bushel. They are sold alive.

Dr. Langlois: There is a South African bulletin on the tagging of crayfish to study the migrations. I think they are working on the larger species. The tag consists of a little metal square fastened by a wire with a loop on the end. This wire is inserted between the segments on the end part of the tail and turned around so that the hook on the loop prevents its easy withdrawal. I had in mind trying to employ this method in order to make use of the many crayfish we liberate to secure information on migrations of crayfish in our waters.

Mr. Elmer Higgins (Washington, D. C.): With regard to the use of crayfish for food, there is a large market for crayfish in New Orleans. It is a very popular dish in many of the French restaurants.

Mr. Hewitt: Do they have the large variety?

Mr. Higgins: They are about four inches in size. The small ones are preferred because of their delicate flavor.

Mr. Hewitt: I have seen them in Europe as large as eight inches long.

Mr. Higgins: Those marketed in Louisiana do not get as large as that. Regarding the tagging of crayfish, Mr. Langlois will be interested to know that the impossible has been done by one of the Bureau investigators in tagging an animal as delicate as the sea shrimp. I have always said it could not be done, but I have changed my attitude in that respect; not only has the herring, one of the most delicate sea fishes, been tagged successfully, but now the shrimp has also been tagged. The method there is the insertion of a nickel pin with two of the common disc tags as used by the Bureau of Fisheries on either end of the pin inserted through the first abdominal segment. The moulting takes place by shedding around the pin. It is worth considering in the crayfish, although this difficulty may be encountered, that the crayfish, having a heavier shell, cannot shed so readily to leave the tag in place.

ARTIFICIAL PROPAGATION OF WALLEYED PIKE

GEORGE E. BUTLER

Gull Harbor Hatchery, Hecla, Man., Canada

Swan Creek Hatchery on Lake Manitoba near Lundar was built by the Government of the Dominion of Canada in 1928, operated by them in 1929 and 1930 and since then has been taken over and operated each Spring by the Government of the Province of Manitoba. It was the privilege of the writer to do three years experimental fishing at this point previous to the construction, to determine the number of eggs that might be expected, and to have had charge of the hatchery operations for four seasons.

Swan Creek is a river 60 yards wide near its mouth and 9 ft. deep. It drains a large inland marsh area with a network of inland lakes and creeks that are ideal spawning grounds. This river has an apparently never-failing run of parent walleyed pike in the Spring, and from one pound net set near its mouth we capture from 15 to 20 thousand walleyes and produce from the Hatchery a distribution of fry of from 35,000,000 to 114,000,000.

Handling such large numbers of walleyes has given us the opportunity to study and improve our technique, and we find that it is possible to hatch 75% to 80% from eggs taken from fish that are ready to spawn, and even the eggs from fish held in retainers will hatch out above 50%.

Last year Hatchery Assistant Sam Sigurdson set up in jars some eggs that were not water hardened, and these eggs turned out to be the best in the hatchery that season. This year we dispensed with the water hardening process in tubs on the hatchery floor and put the eggs up in jars almost as soon as they came into the hatchery. The results were excellent.

Our method of taking eggs is planned to make the operation as speedy as possible as eggs for best results should be washed off as soon after fertilization as possible. We use a float 20 ft. by 5 ft. and 16 ins. high to work in. We have three large tubs of water in this boat to hold parent fish, two for spawners, the other for males. The men scooping from the retainer put all spawning females they find into the two tubs. One man scoops from these tubs to the spawn-taker, and every ten minutes or so a pan of eggs is ready to be washed off. The man who scoops to the spawn-taker also keeps the green eggs and milt continually stirred as they are being taken. When a pan of eggs is ready it is handed over to the man who does nothing else but wash off and stir these newly taken eggs. As soon as the new eggs have absorbed some water and expanded they are put into two pails and another man takes them to shore and carries them to the hatchery, a distance of approximately 200 yards. Thus, our outside operation gives a steady stream of parent fish,

male and female to the spawn-taker; the spawn-taker has a pan of eggs ready for the man washing off as soon as he sends the previous pan of eggs to shore, and the carrier, who stirs the eggs several times enroute to the hatchery so that they will not cake, is kept going fairly steady from the net to the hatchery and return.

At the hatchery the eggs are put into a tub of water, washed off a few times and then put up in the jars. Almost within an hour of the time they left the parent fish, and in no case more than two hours the eggs are set up in the hatchery jars. Once in the jar the eggs are run hard for 24 hours and are feathered continually with a large goose quill for an hour or so until they stop sticking and run freely.

As soon as the dead eggs appear they are syphoned off and jars kept as clean as possible. If the dead eggs lump in the jars the whole is well stirred with a feather and immediately upon settling the dead eggs are syphoned off. Any masses of dead eggs that collect in our jars will very soon sink as there is enough mud in suspension in the water to adhere to these lumps and so make them heavy enough to sink into the good eggs. The stirring process shakes the mud from the masses and allows the dead eggs to float so that the syphon can take them off without removing good eggs.

In the past at Swan Creek we have had serious losses of eggs with gales of wind stirring up mud, and large quantities of this mud coming through the hatchery. With these winds high temperatures would usually prevail and mud and high temperatures, from 65 to 70 ° F, proved fatal to large numbers of eggs,—in particular those eggs recently set up in jars. This was remedied by connecting an intake from the supply pump to the floor tank, so that by opening the valve of the line leading to the tank and closing the valve of the intake from the creek, we could pump the water from the floor tank back to the supply tank and run it through the batteries repeatedly. When the wind abated we would go back to the creek for the water supply.

We propose to cool the water in the supply and floor tank with ice so that with prolonged using this supply, water temperatures will not rise too high.

The fry from this hatchery are in the main distributed on natural spawning grounds within convenient distance of the hatchery, but we have an increasing demand for walleyed fry from persons interested in stocking small lakes throughout the Province, and this year with the assistance of one aeroplane and three trucks an outside distribution of over 4,000,000 fry was made. Some of these distributions were made 300 miles away from the hatchery.

Investigation of suitable lakes after receiving an allotment of fry has proved that walleyes flourish and establish themselves very quickly if their environment provides their needs, and they withstand fairly well the high summer temperatures that prevail in some of these small inland lakes.

HATCHING FRY IN GRAVEL NO. 2

ALEXANDER ROBERTSON

Cultus Lake Hatchery, Cultus Lake, B. C., Canada

In 1919 the writer submitted a paper on hatching fry in gravel which was included in the Society's transactions for that year. The present paper is a sequel covering observations along this line during the intervening seventeen years.

When the previous paper was written, the writer was in charge of Harrison Lake Hatchery, but since 1926 has been superintendent of the hatchery at Cultus Lake which was selected as the location for the Sockeye salmon investigation and hatchery methods in general.

A review of the 1919 paper will show that the writer was then convinced that the system of liberating free swimming fry, which at that time comprised ninety-five per cent of the output of the B. C. hatcheries, was nothing but a waste of time and money as exemplified by the failure of the hatcheries to increase materially the number of fish on the spawning grounds let alone the commercial catch.

It does not require a multiplicity of figures to show, if four years after the liberation of twenty or thirty million sockeye fry in a given district it is found that the return of spawning fish has not increased, that there is something seriously wrong with the system being followed.

A good illustration of this is found in the behavior of the sockeye in Trout Creek, Harrison Lake, at which point the hatchery is located. A local "big" year occurred in this stream in the years 1903 and 1907 and at regular four year intervals thereafter.

Due to the storage of water for a power plant, which also fiurnished the water supply for the hatchery, this stream was under control at all times and it was a comparatively easy matter to trap the fish and take their eggs.

The number of eggs taken in this cycle year varied very little from 1903 to 1919, the maximum being 4,500,000 and the minimum 3,500,000, and in the course of time its return was looked forward to in the hope that an increase in the run of fish would show that the work four years previous had not been in vain.

The runs of 1915 and 1919 having shown no appreciable increase, as the result of the planting of free swimming fry, was evidence enough to show that a change was needed if the operation of the hatchery was to be justified.

With this in view, and having experimented for some years with gravel hatching, it was decided to plant 2,500,000 in the spring of 1920. One million five hundred thousand of these were layered in gravel in the ordinary sixteen inch hatchery troughs and the balance were similarly placed in the waste ditch leading from the hatchery to the lake. No

intermediate device was necessary to deposit the eggs as the water could be turned on and off as required.

The result of this comparatively simple change in procedure was that in 1923, this small stream which, under fry liberation, had never yielded five million eggs, now produced twelve million and several millions more could have been taken if the necessary accommodation had been provided.

At this juncture the obvious thing would have been to plant the whole twelve million, to see if the five fold increase would persist in 1927, but unfortunately this was overlooked and a golden opportunity lost.

It is the writer's firm opinion that had this simple step been taken the results would have placed the B. C. hatcheries in an unassailable position.

About this time, however, it was decided that egg planting could be done just as well in open streams and rivers and this is the policy that has prevailed since then.

During the investigation of hatchery methods at Cultus Lake, egg planting in gravel was tried three times, with eggs from the runs of 1928, 1933 and 1934. The system of planting in open streams, where the eggs were subject to all the vicissitudes of nature, was followed and the annexed analysis shows the destruction wrought by flood and drouth.

The various streams which were used in these trials were under the direct observation of the writer throughout the whole of the incubating and emerging periods and there is not the shadow of a doubt that in the years 1928 and 1934 the eggs marked "dried out" were a complete loss.

In 1933 a severe freshet occurred soon after the eggs were planted and the high percentage of 19.3 for that season is probably due to an overestimate of the damage.

ANALYSIS OF RESULTS OF SOCKEYE EGG PLANTINGS IN GRAVEL IN THE TRIBUTARIES OF CULTUS LAKE

	1928		1933		1934	
	Planted	Hatched	Planted	Hatched	Planted	Hatched
Frost Creek	1,638,000	Dried out	245,270	Washed out	.....	.....
Upper Spring Cr. ..	371,000	371,000	1,177,399	1,177,399	2,715,533	2,715,533
Lower Spring Cr. .	.....	.....	238,670	Washed Out	.....	.....
Watt Creek	.....	.....	1,080,104	Washed out	1,456,000	Dried out
Windfall Cr.	252,000	Dried out	1,276,784	Washed out	1,085,000	Dried out
Smith's Falls Cr. .	105,000	105,000	82,030	82,030	407,327	407,327
East Creek	35,000	Dried out	.....	.....	.....	.....
West Creek	105,000	50,000	.....	.....	.....	.....
Totals	2,506,000	526,000	4,421,814	1,259,429	5,663,860	3,122,860
Yearling Micrants .	43,447	.....	242,500	.....	495,000	.....
% Eggs Planted ..	1.7	.....	5.4	.....	8.7	.....
% Eggs Hatched		3.3	.....	19.3	.....	15.8

The "planted" column shows the gross number of eggs planted and the "hatched" the number that had a fair chance of reaching Cultus Lake as free swimming fry.

"Migrants" are the yearling fish that leave the lake for the sea.

The "planted" percentage is taken from the gross number and the "hatched" those that had a fair chance of survival. While admittedly the latter is the result of observation only and consequently vulnerable, the former can only be admitted by blinding oneself to the true facts of the case. In any event a flexible interpretation is always justified if the aim of the investigation is progressive and not condemnatory.

It is evident from the analysis that Spring and Smiths Falls Creeks behaved excellently throughout the three trials and in fact were responsible for all the success that resulted.

Both are short streams originating in springs and consequently are not subject to the violent fluctuations of mountain streams such as Watt and Windfall Creeks. But unfortunately the planting area in both is limited and their value is still further lessened by the agricultural operations carried on in their vicinities in the course of which considerable quantities of loam are washed into the streams.

In 1934, to demonstrate the ability of the fry to release themselves from the gravel 50,000 eyed sockeye eggs were planted in a small stream formed by the overflow from the settling pond at Cultus Lake hatchery. Under ordinary circumstances this can be controlled and the test considered a partially protected one. Below the plantings a large screened tank was installed and later on 44,699 fry were caught as they descended the stream.

The question of the efficiency of the planting of freshly taken (water hardened) eggs having arisen this same area was planted with 51,940 in the fall of 1934. In February of the following year the highest freshet in the history of the hatchery happened and the beds were swept clear of all the loose gravel and only 1,699 fry were recovered in the tank.

In November 1935, fresh gravel having been hauled to replace that washed away, 53,284 freshly spawned eggs were again planted and, as nothing untoward happened during the winter, 42,435 fry were captured in the tank this spring.

Taken in the tank along with the fry were three trout three inches long and fifteen two inch fish and the depredations of these agile little specimens must have reduced the total considerably.

The high percentage resulting from this planting of freshly taken eggs is all the more remarkable when it is noted that, had they been held in the hatchery to hatch, they would have been subject to a ten per cent loss in empties and weaklings.

The fact that they were washed out in the previous trial accentuates the urgent need of protection.

Despite the progress made in practically every line of endeavor, and the great potentialities available in the 4,500 eggs each female sockeye contains it is concluded that the preservation of this fish by artificial methods is hopeless. It is certain, however, that this admission of failure will not deter other investigators from their efforts to solve this most

alluring problem the solution of which will eclipse every discovery since the genesis of fish culture. Now that the fish are to be left to their own devices the first thing that comes to one's mind is, in what respect does their spawning technique excel, that so much dependence can be placed on it.

The writer, while at Harrison Lake, counted the contents of sixteen salmon nests and found the average to be approximately 500. This represents less than one eighth of the total egg content of a female and therefor it is obvious that the alleged superiority lies in some other direction than in numbers. Eliminating this factor, the problem narrows down to the point that there is something inherently good in the underground contact of egg and gravel and the detention of the fry in darkness.

The writer does not claim to have read all the literature on the life History of the Sockeye Salmon but can confidently say that apart from the references made in his previous paper he has never heard of anyone investigating this stage of their existence. For some obscure reason there appears to be a distinct hiatus at this period of their life history, when a thorough understanding of what transpires would explain why the hatcheries have been unable to operate with success. It is incomprehensible to one who has been connected with the B. C. Salmon hatcheries for thirty-four years that the importance of the larger eye and capability of the oblique dart of the gravel hatched fry has never been recognized, for there is no doubt that, after their two months stay in smooth troughs, the hatchery product lose all sense of self-preservation.

The importance of the diatomaceous substances in which the eggs become embedded soon after being deposited is another feature which has been overlooked, though its value in fungus control is very easily demonstrated.

The physical superiority of fry incubated in contact with this substance and those without, is so pronounced as to be discernible at a distance of twenty feet.

The writer has now had the opportunity of participating in four trials of gravel planting and is firmly convinced that at least a five fold increase, over fry planting or natural spawning, will result if the beds are adequately protected.

For some inexplicable reason it seems to be the general opinion that gravel hatching and risk are inseparable.

It would be just as reasonable to try to operate a hatchery with a pipeline liable to fall apart at any moment as it is to plant eggs in a stream known to go dry two seasons out of three.

Until fully protected gravel hatching has been given a fair trial it cannot be said that the hatcheries have failed.

REPORT ON THE EFFECT OF GRAVEL IN RACEWAYS

JAMES SAVAGE

Toronto, Ontario

Gravel has been used very extensively in rearing stations as a covering for the bottoms of raceways in which trout are retained, and its use is recommended in several publications, but in no case so far as I am aware has any attempt been made to point out its supposed advantages, other than that it approximates a natural condition and encourages the growth of food organisms. Some doubt has recently arisen as to the advisability of continuing the use of gravel in raceways, and it is hoped that this paper, which is based on observations made over a period of four months, will help to decide the question. The work was carried out at the Sault Ste. Marie Trout Rearing Station during the winter of 1934.

STERILIZATION

Whenever fish are treated for disease it is of paramount importance that the tanks in which they were retained be thoroughly sterilized before the fish are returned, otherwise reinfection is almost certain to take place. It is practically impossible to sterilize tanks containing gravel as bacteria are particularly abundant on the slimy coating of gravel particles, and in the decaying excrement which accumulates between the particles. It is also doubtful if a disinfectant solution such as potassium permanganate will penetrate to all the interstices in a reasonable length of time.

During the first two years (when they are retained in the raceways) it is almost inevitable that trout will require treatment for some of the many diseases to which they are subject. The same is true when salting fish in order to kill fungus and unicellular parasites. In the length of time that the fish can be left in the salt solution it is unlikely that it will penetrate throughout the gravel and kill all the infection lurking there. There is no doubt that there is danger from infection among the gravel as will be shown later. Therefore, the presence of gravel in the tanks constitutes an obstruction in the treatment and prevention of disease, and for this reason alone should be excluded unless it can be shown to have some indispensible function.

CLEANING

It has been my experience that the smoother the bottom of a trough or raceway the easier it is to keep clean, in fact the current of water passing through, together with the movements of the fish in the water,

is often sufficient to keep the excrement washed down close to the screen, where it is harmless to the fish above and can be siphoned off at frequent intervals. Even slight irregularities in the wood will allow dirt to accumulate, and it is advisable to sandpaper the bottom of the troughs and tanks before applying tar which should be spread on as smoothly as possible. These advantages are lost when gravel is used, as the dirt and excrement will not slide over the bottom and the whole tank must be gone over with an instrument known as a scraper which not only scrapes the dirt from the gravel but spreads the gravel on top of the dirt. Without gravel a tank can be *thoroughly* cleaned in less time by the use of a wing feather attached to a curved stick* which is used to sweep down any debris which is too heavy for the current to wash down. The excrement being of a light colour is very obvious over a black bottom and every particle can be removed. In cases where gravel is used it is found that even when apparently clean it contains large amounts of decaying food and excrement.

Examination of Gravel

One square foot of gravel (apparently clean) was taken from a raceway containing fingerlings and carefully examined. It was found to contain 73 c. c. of moist organic debris (approx. three fluid ozs.). An examination of this material revealed that 95% was excrement in various stages of decomposition, approximately 4% consisted of undigested particles of liver and the remaining 1% included insects larvæ *(Chironomus)*, algae, fungus, sediment and decayed leaf tissue. The fungal growth were detected on the uneaten food and would be a continual source of infection to any fish which was roughly handled or injured in any other way. This applies not only to the fish in the raceway but to any fish below. The insect larvæ and algæ do not cause any ill effect, in fact both are eaten by the trout, but they were not found in sufficient quantities to be considered as an important contribution to the diet. On the other hand I have frequently found large carniverous insects in tanks containing gravel, but not as yet in tanks without gravel. It is probable that the eggs and immature stages find suitable lodgment among the gravel. I have found fingerlings as large as two inches killed by *Benacus*.

Many other invertebrates such as snails and crustaceans which would thrive on a gravel or dirt bottom act as natural food for trout, but they are also intermediate hosts for internal parasites of trout and their value in the former capacity is outweighed by their menace in the latter.

Rate of Decomposition

Experiments were performed to determine the rate of decomposition taking place among the gravel and the amount of oxygen used in the

* An old hockey stick, when cut down, serves the purpose admirably.

process. This was done by placing in the bottom of a jar (Fig. 1) some gravel exactly as it was on the bottom of the raceway. The top of the jar was sealed and a similar jar containing the same amount of water but without gravel was used as a control. Both jars were submerged in running water so that the temperature remained constant at 42° F. The oxygen content of the water in the jars was measured at intervals and it was found that decomposition was taking place slowly, since 36 hours were required to lower the oxygen content of jar A 1/5 c. c. per litre. The withdrawal of oxygen from the water is therefore not an important factor especially where the fish are not overcrowded and where there is a good flow of water. However, slow decomposition means the accumulation of toxic substances which would be quickly reduced to harmless inorganic matter if decomposition were more rapid. On the other hand if decomposition were rapid, as it probably would be at hatcheries where the water is warmer, the withdrawal of oxygen would be a factor worth considering especially if the water supply were scanty and the fish numerous. Whether the decomposition is fast or slow the accumulation of organic waste products is undesirable.

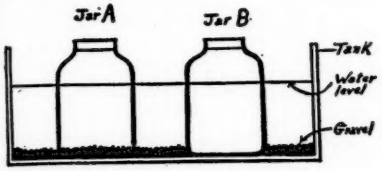

Fig. 1

Observation of Fingerlings

Observations were made on the behavior of fingerlings retained in a tank with gravel as compared to similar fish in a tank without gravel. (Fig. 2). Tank C contained gravel and tanks A and B were without. Fingerlings were divided between tanks A and C (tank B at this time contained other fish) November 1st. On November 24th Fin-rot was detected among the fish in tank C and they were treated in the prescribed manner with copper sulphate solution. These fish were then divided between tanks B and C both of which were treated with permanganate solution using the same amounts and for the same length of time. It was estimated that approximately 30% of these fish showed evidence of fin-rot but

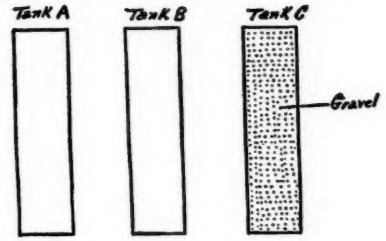

Fig. 2

their condition was not serious. Following treatment, tanks B and C were compared and in tank C it was found that the condition persisted more noticeably than in tank B so that further treatment was required (Jan. 14). When the fish from tank C were removed to another tank after treatment the gravel was removed from tank C and it was properly sterilized. The fish were then replaced and continued to progress favorably.

Some fish in tank A showed evidence of fin-rot becoming noticeable first on December 18th. The number of cases was then to the remainder of fingerlings as 10% to 30%. It will be seen that fin-rot occurs even without the presence of gravel but in a milder form which can be dealt with in a definite way. Where gravel is present the condition is more serious and the treatment less effective due to reinfection. This is probably also true in the case of other bacterial diseases or unicellular parasites.

Summary

ADVANTAGES	*DISADVANTAGES*
Natural bottom.	Practically impossible to sterilize.
Natural food.	Difficult to clean.
	Retain debris inaccessibly.
	Harbours insect enemies and intermediate hosts of parasites.
	Cost of transportation, screening, etc.

Although I do not advocate the use of gravel in raceways I do not mean to infer that it is the sole cause of disease among fish, but it appears to have no essential function and has many positive disadvantages as pointed out above. As far as approximately a natural condition is concerned I believe it is best to be consistently un-natural in the handling of young fish up to the time that they are placed in the ponds.

NOTES ON THE FOOD OF *DAPHNIA PULEX* (DE GEER) IN FERTILIZED WATER

M. W. Smith

Atlantic Biological Station, St. Andrews, N. B., Canada

In recent years the writer has been carrying on experiments to determine the effect of various fertilizers upon the production of plankton in fresh water (Smith, 1932, 1934). What constitutes the food of the zooplanktonts found in fertilized waters is a question of decided importance in estimating the value of a fertilizing procedure. It has been found that *Daphnia pulex* (de Geer) lives very well under experimental conditions created by fertilizing, and, since it is among the larger of the Cladocera, and therefore of more food value for young fish, it becomes pertinent to enquire what forms of organic matter constitute its food.

The literature upon the food of zooplanktonts is extensive, but we will confine ourselves mainly to the data available for *Daphnia.* In general the various substances that have been considered by investigators on the subject, to form the diet of the zooplanktonts may roughly be divided into three classes, (a) dissolved organic material, (b) particulate dead organic matter and the omnipresent bacteria, and (c) the living algæ.

Knörrich (1901), working with *Daphnia,* concluded that dissolved organic matter was utilized by these forms sufficiently to maintain growth and reproduction. However, Wolff (1909) pointed out that in the hay infusions, as used by Knörrich, there were quantities of particulate food. As early as 1877 Weismann stated that daphnids lived almost entirely on fine decomposition products of organic substances. Woltereck (1928) found that the pond forms such as *Daphnia magna* and *D. pulex,* could be fed quite well on "mud" and organic detritus, but that pelagic daphnids did not live well under experimental conditions on detritus derived from filamentous algæ, etc., although the intestine might be tightly packed with such substances. Naumann (1918, 1921) made extensive studies on the types of foods present in fresh-waters, on the manner of feeding of limnoplanktonic Cladocera, and on the intestinal contents of these forms. He states that Cladocera are effective filters but feed in a non-selective manner, and that very fine detritus ("staubfeine Detritus"), as well as bacteria, are the most important sources of food. Algæ, except for some of the Chlamydomonadaceæ, are not digested he says.

In keeping with the observations that daphnids use organic detritus and bacteria as food, we have successfully grown *Daphnia pulex* in cultural jars by additions of 0.15 and 0.25 gm. of herring meal per

litre to spring water. They died, however, if introduced simultaneously with the meal. It was necessary to allow the water and meal to stand for some time (about two days on the average) before putting in the daphnids in order that they might survive. This would seem to indicate that bacteria constituted the principle food element in such cultures. *Daphnia pulex* reproduced parthenogenetically under these conditions, although there was a tendency toward ephippial production, even when the culture was comparatively "fresh." It might be well to indicate at this point that Banta and his co-workers have shown that bacteria form an adequate food for several species of Cladocera (Banta, 1921; Stuart and Banta, 1931; Stuart, Cooper and Tallman, 1931).

Klugh (1927), by careful miscroscopic observations upon the food ingested and its subsequent digestion, and by rearing Cladocera in pure cultures of pamelloid forms of algæ, has advanced fairly conclusive evidence that the smaller algæ can constitute a dominant food of these forms. Thus, he observed that *Daphnia pulex pulicaria* fed upon pamelloid forms of algæ, very small colonies of *Volvox aureus* and *Chlamydomonas communis*. Examinations made by the writer of the intestinal contents of *Daphnia pulex* have revealed the presence of *Scenedesmus* and other minute Chlorophyceæ, along with an amorphous mass of gray-green material, which probably consisted of detritus, disintegrated algæ, or minute nannoplanktonts. The greenish tint of the mass, more green in the fore-gut than farther back in the intestine, would indicate algæ, and point to its subsequent digestion.

Some pertinent data on algæ as food of *Daphnia pulex* were obtained from an experiment that was carried out to ascertain the rapidity with which an algal culture would be depleted by a population of this species. Two hundred cubic centimetres of a dense culture of *Scenedesmus, Ankistrodesmus* and *Selenastrum,* and other minute Chlorophyceæ, were put into each of three jars. Into two of these *Daphnia pulex* were introduced in numbers of five and fifty. The temperature of the water varied from 24.4° to 27.8° C. The initial count, the control count, and the counts with five and fifty *Daphnia* are shown in the accompanying table. The percentage increase or decrease of the algæ over the initial count is given in brackets. The number of *Daphnia* was constant, kept so by beginning with young individuals from one clone, and discontinuing the experiment when the first young appeared.

TABLE 1. ALGAE AS FOOD FOR DAPHNIA PULEX. (NUMBER OF ALGAE PER LITRE IN MILLIONS)

	Initial	After four days		
		Control	With five	With fifty
Scenedesmus	67	85 (+27)	89 (+33)	56 (—15)
Ankistrodesmus	108	120 (+11)	103 (—7)	63 (—42)
Selenastrum	32	31 (—3)	29 (—9)	21 (—34)
Minute Chlorophyceae	2987	3097 (+4)	2346 (—21)	1153 (—61)

It is readily seen that these algæ differ considerably in their acceptability as food for *Daphnia pulex*. The minute Chlorophyceæ were

eaten most readily, *Selenastrum* and *Ankistrodesmus* to a lesser degree, and *Scenedesmus* least of all. In the culture with five *Daphnia, Scenedesmus* was evidently not consumed at all, and *Ankistrodesmus* and *Selenastrum* only sparingly. In the culture with fifty *Daphnia* all algæ were eaten, but with a preference for the smaller forms. It would seem that, as the supply of the more desireable minute Chlorophyceæ decreased, the cladocerans turned to the other forms with greater avidity. This indicates that *Daphnia pulex* is able to exercise some discrimination in its feeding, contrary to the opinion expressed by Naumann. In this connection, Klugh (1927) helps to substantiate our observation by having actually seen *Simocephalus serrulatus* neatly eject any undesirable material.

From the results obtained by us and from the data in the literature, it appears that *Daphnia pulex* consumes detritus with bacteria as well as algæ. The preference of any one food element probably depends upon its quantity and availability. Also *Daphnia pulex* apparently discriminates among the materials to be eaten, particularly when feeding upon algæ. The apparent wide variety of food acceptable to *Daphnia pulex* makes it a very suitable form to cultivate in fertilized waters.

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IDENTIFICATION OF FACTOR "H" IN THE NUTRITION OF TROUT

EDWARD R. HEWITT

New York, N. Y.

In 1927 Dr. C. M. McCay and W. E. Dilley made public their discovery of factor "H", as they provisionally called it. This was the result of a series of carefully conducted and controlled experiments. They showed that trout could not be kept alive for long periods on any known dry food. After some time of growth they invariably died within about five months or less. They did not report any pathological studies on the cause of death and I have found none in the literature. It is probable that the lack of factor "H" so weakened the fish that they succumbed to a variety of diseases depending on the environment.

Subsequent work by Dr. McCay made it clear that factor "H" was destroyed by canning in the ordinary way in the presence of air, but was preserved to a large extent if air were excluded by an inert gas such as nitrogen. He found that a small amount of fresh animal food added to a dry food diet would carry trout over long periods without excessive mortality. All varieties of fresh animal foods seemed to have this property, but liver appeared to be the most potent of those tested. It was also demonstrated that factor "H" was not any of the then known vitamins A, B, C, D, or E.

My own interest in this subject arose because I had been marketing dry trout foods for some years and advising customers as to the use of fresh foods in addition. I was desirous of incorporating factor "H" with my dry foods so that the trouble of handling fresh foods could be avoided. All my experiments up to last Autum were failures and factor "H" remained a mystery. The idea then occurred to me that a possible way to solve this problem was to brush up on Biochemistry and see if there was any known organic body which might possibly be factor "H" and try it out.

This body must exist in all fresh animal tissues and be altered by air oxidation on drying. These were the main clues to follow. It was found that Phosphatides occur in all animal cells and seem to be absolutely necessary to life processes. They are almost the only class of bodies universally present in all cells. They are maintained in the cells even under conditions of emaciation. They are rapidly oxidized in the air, and in the presence of light. A body of this series might be the elusive factor "H." In order not to waste time on a useless quest, I consulted my friends at the Rockefeller Institute as well as at the Metabolism Department of the New York Hospital, and found that they felt that one of the Phosphatide group might be factor "H" and

that it was worth following this clue carefully. The library of the Institute, one of the best on biology in the world, was kindly put at my disposal and an excellent chance for study thus became available.

The more the matter was gone into the more probable it became that some member of the Phosphatide group must be factor "H." In order properly to understand this subject it will be necessary to give a condensed description of these bodies. According to Harrow and Sherwin, one of the latest and best books on Biochemistry, only three phosphatides have up to the present been identified with certainty in animal tissues. They are closely related bodies of rather peculiar composition. All contain Phosphoric acid linked to one saturated and one unsaturated fatty acid. Lecthin and Cephalin have glycerophosphoric acid while Sphingo myelin has only phosphoric acid but no glycerol. Lecithin and Sphingomyelin have Choline linked in the molecule while Cephalin has in place of this amino ethyl alcohol. Lecithin and Cephalin exist in all the muscular tissues and organs of the body while Sphingomyelin is mainly present in the brain and nerve cells and to a small extent in the liver and kidney. As the Phosphatides all contain one saturated and one unsaturated fatty acid there could theoretically be as many phosphatides as there are fatty acids. However, the actual number found in tissues seems to be small, and only a few fatty acids exist in them. Because of this variety of fatty acids and of their different molecular weights it is not possible to assign any definite molecular weight to Lecithin as such. In my analysis I have assumed a weight of 300 as representing an average weight for calculation.

In insects, the principal diet of American trout, the Sphingomyelin is distributed all through the body in the nerve ganglia because insects have no large centralized brain. In consuming insects, trout get a much larger proportion of Sphingomyelin than on a diet of fresh animal foods. It is possible that this may be one of the reasons for the beneficial effects of the insect diet. A test of feeding brains to trout proved a failure because they contain too large a percentage of Cholesterol which accumulates in the liver and causes degeneration and death in a month or two. This subject deserves further study.

The Phosphatides are all readily oxidized by air, particularly on drying, and their properties are much altered. The oxidation seems to occur at the double bonds of the unsaturated fatty acid. We do not yet know with certainty what role these acids play in animal metabolism but they must be important. All Phosphatides are readily split into their component parts by the fluids of the digestive tract. Lecithin is supposed to play a very important part in the distribution of fats in the circulation but its exact function is not yet surely known. Much study is being placed on this subject at the present time as it is regarded as of great importance.

Trout suffer from fatty livers on certain diets, both fresh and dry, and under certain water conditions. The cause of this disease is not

yet completely understood. Last year my trout developed this trouble. Dr. Peyton Rous, who happened to be visiting me, examined the fish and diagnosed the disease. He took specimens to the Rockefeller Institute and made sections of the liver and other parts of the fish showing the degeneration which was also well marked in the kidney. This started another line of inquiry. Fortunately I came upon the work of Dr. C. W. Best (Biochemical Journal Vol. XXIX No. 12 pp. 2651—2658, 1935) which showed the property of Choline in controlling the deposition of fats in the liver. He demonstrated that fatty livers in animals could be cured by a diet containing sufficient Choline. This was of the greatest interest because Lecithin, which I suspected as being factor "H," contains 15% Choline. However, Choline does not cure fatty livers due to Cholesterol.

In order to get information for the study of Phosphatides used by trout, it seemed necessary to know the amounts of them in the foods consumed. Completed reliable data on this subject were not available and the figures found were most contradictory. The methods of analysis usually employed seemed complicated and too difficult to carry out for the number of tests I wished to make, so the method suggested by Hoppe-Seyler many years ago of determining only the phosphoric acid and calculating the Phosphatides from this was adopted. This is far simpler than other methods and probably just as reliable when we consider that there are probably no other bodies containing phosphoric acid which are extracted by hot alcohol from dried animal tissue.

Complete extraction of the dried material passed through a 60 mesh sieve was made with hot alcohol in Soxhlet extractor for 6 hours. The alcoholic solution was evaporated after the addition of a small amount of caustic potash to fix the phosphoric acid. The residue was burned in an iron crucible with the addition of potassium nitrate at the end, to assure complete combustion, and the ash taken up in water and acidified with nitric acid. This was filtered and precipitated with Ammonium Molybdate solution and the yellow precipitate weighed in a Gooch crucible after drying. This weight multiplied by .4239 gives the weight of Phosphatides calculated on a molecular weight of 800. While this method may not be absolutely accurate it gives good comparative figures as to the amounts of Phosphatides contained in foods.

The following analyses are among those made in this way and give the comparative amounts of Phosphatides contained in the dry material.

	% Phosphatides in Dry Material
Beef Liver, 26% Solids	22.4
Sheep Liver, 32.1% Solids	19.2
Pig Liver	18.6
Salmon Liver (Canned)	2.79
Beef Brains, 22.7% Solids	27.6
Beef Heart, 22.7% Solids	15.5
Pig Heart, 25.3% Solids	13.86
Beef Melts, 27.7% Solids	7.2
Pig Melts, 27.7% Solids	11.9
Beef Lights	11.1
Hamburger (Lean Beef)	9.27
Small Herring (4" Long)	5.12
Butter Fish, 28.3% Solids	4.32
Small Suckers (4" Long)	6.96
Salt Water Shrimp	5.66
Haddock roe, 28.84% Solids	14.62
Salt Water Mussels	7.51
Helgramites	9.12
Midge Larvae	7.91
Crane Fly Larvae	6.53
Stone Fly Nymphs	5.75
Fish Worms (Red Small)	7.51
Dry silk worms which had been steamed	.81
Silk Worm Oil	0
Yellow Salmon Oil	.72
Red Salmon Oil	.42
Salmon Egg Meal	6.50
Menhaden Fish Meal	3.46
Cotton Seed Meal	2.30
Dry Skim Milk	5.35

An inspection of this table reveals some interesting things. Beef liver is generally regarded as slightly better food than sheep or pork liver. It is slightly higher in phosphatides. Beef melts are found to be much inferior to pork melts as a food, and they contain much less phosphatides. Fish contain slightly less phosphatides than insects and are not as good a food for trout. Among the insects of course those which are soft, without shells, have a higher Phosphatide content than those with hard outer parts.

Having decided that the unoxidized phosphatides were probably factor "H" and necessary to maintain the life of trout, I started experiments to see if this could be proven. Where were unoxidized Phosphatides to be obtained in sufficient quantity for a feeding test? It is most difficult to make these free from oxidation in small quantities in the laboratory. The egg Lecithin I purchased from Germany was badly oxidized and very expensive. Fortunately I have among my friends Dr. E. E. Free who is a general consulting scientist. On one of my frequent visits to his office there happened to be on his desk a small bottle of a waxy looking material. I enquired what this might be. He told me that it was vegetable Lecithin made from soy beans, and that he had been retained to find new commercial uses for the product. This is now made in large amounts for various purposes but particularly to prevent the bloom on chocolates and to keep cakes fresh. It is also

used in leather dressing and mayonnaise. Dr. Free put me in touch with the manufacturers, who furnished samples for my tests. These were found to be composed of Lecithin and Cephalin with no other detectable Phosphatides present. To prevent oxidation 30% of a neutral fat was incorporated. As this material is made in large quantity by means of solvents and the fat is present while the Phosphatides are still in solution, there is small chance for any oxidation and the material was found to be excellent. Chemistries stated that there was no difference between vegetable and animal lecithins.

A study of trout feeding tests, of which a large number was available, indicated that trout did well when the percentage of unoxidized Phosphatides in the diet was five or over. When it was as low as three per cent mortality was much higher and the growth far less provided too much food was not fed. The percentages of Phosphatides in the diet were calculated by using the analyses listed in the previous table. It will be noted that the percentage of Phosphatides in an insect diet is higher than five but it must also be remembered that trout do not consume as much insect food in a day as they do of hatchery foods. I decided to try the experiment by using 5% Phosphatides in the dry food.

On January 15, 1936, forty brook trout weighing sixteen to the pound were placed in a round tank in my hatchery water which comes from the rock, and is tightly sealed in, with no chance for any insect life to enter it. These fish were fed on dry silk worms which had been steamed and which feeding tests by Mr. Surber had shown would not maintain trout life more than a few months without fresh food additions. By April 4th, these fish ceased growing and began to look sick. Five percent of vegetable Lecithin was then added to the same diet and the fish grew 25% in two weeks and have continued growing on a straight line curve (as plotted on logarithmic paper) until July 21 when this paper is written, which is over six months. They are fine healthy fish of light color and there were no deaths up to that time. Dr. McCay writes me that if I am able to keep trout in good health and growing well for five months that the diet must contain factor "H." Two more lots of trout were started on this diet early in May. One of two-inch brook trout and the other four-inch brown trout. Both are still doing well to September 15th. I am now feeding considerable numbers of trout on dry food diets with Phosphatides added and will soon have my whole hatchery on this type of diet if it continues to be satisfactory.

More work by others must be available before the proof that Phosphatides are factor "H" will be conclusive, but I firmly believe that this will be found to be the fact.

It is significant that these tests were made with vegetable Phosphatides and not those derived from animal sources, as this eliminates the chance that it was some other animal product in small amount

which produces the effect noted. It is not at all likely that the vegetable product contains any important bodies other than Lecithin and Cephalin. It would seem more probable that the factor "H" effect was produced by the Lecithin rather than by the Cephalin but it might be due to either or to the combination of the two. Only feeding tests with these bodies carefully separated and free from oxidation could settle this point. If possible, I plan to conduct these experiments this coming year and complete the identification of factor "H" as one definite body or it might be called vitamin. This is, however, only of scientific interest as it is not practical to separate these bodies commercially.

Much work has been devoted to the methods of using Lecithin in connection with dry foods practically. The Commercial Phosphatides available are like heavy greases or waxes and cannot easily be mixed evenly with dry foods. Fortunately these bodies are hygroscopic and will form water emulsions if treated in the right way. Such an emulsion is now in use having the right amount of water and Phosphatides in it for mixture with dry foods to make them of the right consistency for feeding with the minimum of waste. This emulsion is preserved with a suitable antiseptic which is not in any way injurious to trout and will keep in cans indefinitely. This makes the matter of feeding dry foods one of the greatest simplicity for the trout raiser. All he has to do is to mix the emulsion with the dry food and feed at once. Trout are crazy for this type of food after they have once had it.

A patent for the use of Phosphatides with dry foods for trout feeding is under application but it is too early yet to know what claims will be granted.

It will be of interest to trout culturists that dry foods with the right amount of Phosphatides for continued growth and health can be sold from 12½ to 15 cents a pound in moderate quantity and for less in larger amounts. This will effect a very substantial saving in the cost of the foods for raising trout at the present time, besides giving some assurance that the price of the food used will not fluctuate to any such extent as it has been doing in the last few years. There is every probability that Soy bean products will increase in industry.

When we consider that the cheapest fresh trout food at present is Pig melts, costing about 5 cents a pound, this brings the dry material cost to 18½ cents. Sheep plucks are quoted at 8 cents a pound and this would make the dry material cost 30.7 cents a pound. Liver which is now from 11 to 15 cents a pound depending on the locality, would cost 44 to 60 cents a pound for the dry food it contains. At this price it can be used only for feeding small fish.

No doubt trout culturists will soon work out the best and most economical way to use Phosphatides in the diet of trout. The subject is too new to be able to say just what the best method will prove to be, or what quantity is absolutely necessary in the trout diet. These

matters will work themselves out in time. One season is not enough to indicate what is the right diet for fish which must be carried two or even three years in the hatchery. We may be able to dispense with fresh foods entirely, as I hope, or again, it may be found necessary to still use some fresh foods. Only longer experience can show what must be done. However, it seems evident that we can now displace a far larger amount of fresh foods by dry foods than has been heretofore possible, and in this way the cost of raising trout will be cheapened by the lower cost of the food and also by the less amount of labor involved. I will be very much gratified if my work on this subject leads to a practical improvement in trout culture. I wish to close by thanking Dr. Davis for his kindly help and encouragement.

DR. HEWITT: Mr. Surber at Leetown has made elaborate food tests for me during the last two or three years, and I have figured out the amount of actual phosphatides that was in the food that he was successful with and in the food he was unsuccessful with. I found both in his figures and in Dr. McCay's figures that when the unoxidized phosphatides were about three per cent the trout would live but the mortality would be rather high in six to eight months and the growth would be under normal; whereas when the phosphatides were up around five per cent the growth was normal and in every case the mortality was very low. So that it looks as if about five per cent were necessary.

Someone asked me yesterday why we could not just feed soya bean meal. Soya bean meal contains only from one and one-quarter to two and one-quarter per cent phosphatides—it varies with the type of bean; but it doesn't contain enough to do any material good, so that it has to be separated out and mixed in.

I do not know whether this type of food will develop eggs. These fish have run seven and a half months and they are in perfectly good condition. I have two other lots that were started on the first of May; there has been almost no mortality among them and they are growing beautifully. I did find, however, that these fish were very light in color on certain diets, especially where I fed a large proportion of dry milk in the dry food diet. As soon as I put in salmon egg meal the color immediately came back in the fish and the fins became nice and red in about three weeks. So that evidently the coloring matter has to be provided from some other source.

Trout culturists will work out the best method of using this thing; it is too new to know what the results are going to be, but I anticipate it is going to be used on a very large scale. If this paper is not as complete as it ought to be, you must make allowances for me, because my main job is acting as consulting engineer for the Mack Truck Company. I am not a professional trout culturist; I do this in odd times in my own laboratory at my house and at the hatchery, so that it is not a professional job. I want to thank Dr. Davis for the very great help he has given me and the interest he has taken in my work; I have been in consultation with him since I first began it, and he encourages me to continue with it.

WHY IS THERE NO TEXT BOOK ON FISH CULTURE?

J. E. Bost

Director of Fish Culture, Game and Fish Department, Greer, S. C.

Sometime ago I wrote to Dr. G. C. Embody of Cornell University to inquire concerning the best text book on Fish Culture, and to my astonishment he replied that there is now no available text. Surely hatchery superintendents and their helpers, as well as students of Fish Culture, are handicapped because of this lack. Can we avoid feeling behind times in our efforts at furthering a study that can claim no recognized text? In talking with School Superintendents and College Presidents I find that this need is generally acknowledged.

I fear that the average student's ignorance on the subject of fish culture could be compared with that of the New York school boy, who, when asked to describe a horse said that a horse had a head, a tail, and a leg on all four corners. It seems that the majority's knowledge of fish has progressed but little since the time of Jonah and the whale. Consider for a moment the interest that would undeniably arise if we had a good text book on fish culture. First, our hatcheries' betterment would be more apt to result from the care of competent, well-informed men whose enthusiasm had been stimulated by the availability of a good foundation for their knowledge. Second, it is plausible that authentic, organized information would inspire confidence in and more methodical attention to hatchery work. Third, the interested sportsman would be benefited. Lastly, our problems would be lessened if we were able to secure from schools or colleges young men trained to give satisfactory service. With this aid our progress would increase and our methods tend to be skilled instead of experimental.

It would be advisable to put these facts in simple language. I believe that we should classify all fresh-water fish into their respective families; then, state the official Latin name, the common English names used in various localities, the habits, and the type of food necessary for propogation. A colored photograph of each particular fish would be helpful and instructive.

The American Fisheries Society is capable of seeing that this guide and reference is edited. Surely cooperation can be enlisted in getting the funds for this necessity.

Discussion

The Secretary: We have a Committee on Common and Scientific Names of Fishes which next year proposes to get out a check-list similar to that published by the A. O. U. with respect to birds so that we shall have in that check-list all the scientific and common names, but that of course will not be the book you refer to on fish culture.

DR. BOST: In my contact with hatchery men—and I have visited a lot of hatcheries—I find that they want something of this kind. They feel that you scientists are shooting away over their heads, and they would like to have some of your discoveries boiled down so that they can make a study of matters pertaining to their particular problems without reading a great deal that they feel they do not need. They also take the view that with the work they have in hand they have little time to read, and they would like to have the information in condensed form. As I pointed out in my paper, many school superintendents have asked me why there is no text book on fish culture. There has been quite a little talk about adding a chair of Fish Culture at Clemson college and building ponds there; I had an interesting talk with Dr. Sykes of that college, but he just threw up his hands and said: "We do not know where to start." I am new in this work and I believe a textbook is something we need very badly. I would like to hear some discussion on it.

MR. HIGGINS: I believe the question, "Why There is no Text Book on Fish Culture?" can be answered briefly by saying there is no one in the United States capable of writing such a book at the present time—and I am casting no slurs on any one. That is due primarily to the great diversity of activity in the field of fish culture, the wide differences between the fishes that must be cultivated and the problems related thereto. To such an extent is this true that no specialist in this day of specialization is equally experienced in all the fields. I should like to call to your attention, if I may, without boasting, the fact that a text book on fish culture is emerging from the experience of all fish culturists and from the research of investigators in this field, which is intended to carry to the beginner, the average workman in the hatchery, the simple facts that he must know to meet his daily problems. This is coming out in the form of a monthly mimeographed bulletin under the title of *"Progressive Fish Culturist,"* and is distributed by the Bureau of Fisheries. We recognize the fact that fish culture is not a science alone; in addition to being a science it is still a craft. This fact is made evident by the wide differences of opinion on many subjects in connection with which questions arise to which as yet we have no final answer. The function of the Progressive Fish Culturist—if you are not already acquainted with it, you should by all means ask for it; it is free—is to bring out in its columns these differences of opinion from month to month. I believe a file of that little magazine will eventually provide a great wealth of material that the investigator can compile without a great deal of labor and that will provide the basis for a text book on fish culture in the future. I should like to suggest to this body now that a more comprehensive journal should be issued on this very subject. Perhaps it may be said that a text book cannot be written now, but a journal published in permanent form under the auspices of this Society and with the cooperation of all its members who are in the field of aquiculture would aid immeasurably in the compilation and publication of an official text book on this subject. The present mimeographed publication lacks permanence and is too brief, too limited in its scope to cover adequately this very important field. At various times the Society has experimented with the publication of its proceedings in monthly or quarterly form. Forty years ago there was a journal on fish culture which ran two years, was bought up by a sportsman's journal and thereafter faded from the picture. I do think that at the next meeting of this Society there should be definite consideration of this question of a monthly publication on fish culture, and a place should be provided for it on the program. In fact I give notice now that at the next meeting I shall propose such a plan, and in the meantime I ask that you all consider it and come prepared to give your best judgment on what can be done towards answering definitely and finally the question Dr. Bost has raised.

THE PRESIDENT: Thank you, Dr. Higgins.

DR. HUBBS: Has the Bureau of Fisheries given consideration to a revision of the Manual on Fish Culture which was more or less of a text book on fish culture?

THE PRESIDENT: Yes, that is being considered.

DR. LOUIS E. WOLF (MICHIGAN): It is a little late for the appointment of committees, but would it not be well to appoint a committee to look into the matter during the year?

THE PRESIDENT: If it is the wish of the Society.

DR. WOLF: I would move that a committee of six be set up to look into the matter during the coming year.

DR. BOST: I second the motion.

THE PRESIDENT: It has been moved and seconded that a committee of six be appointed to consider this question of a text book on fish culture. Is there any discussion?

(The motion was carried unanimously.)

MR. GUY LINCOLN (MICHIGAN): I wonder if it would be out of place to cite any experiences in the use of the federal fisheries text book. Some years ago when Michigan was starting out on its rearing pond system to increase the production of brook trout the old custom was that if we put in 50,000 or 100,000 fish to a hundred-feet length of pond, with a width of perhaps sixteen to twenty feet and two feet of water, it was not considered to be overstocked. In the Jordan River we had a series of ponds the total length of which was over a thousand feet. We put in there 850,000 of the nicest brook fingerlings you could see, and they did very well for two or three weeks. Mr. Cook, who was starting new with us then, gave us this text book and said, "If anything happens, study this book, and you will know what to do." We studied the book as much as we could, and when things began to happen we started to doctor and the fish grew steadily worse. Right away we notified Mr. Cook; the Fisheries Institute at Ann Arbor was communicated with and they sent a man over to investigate. After investigation he said: "Well, it is such and such a bug"—excuse me for not knowing the exact technical name—"and it affects the gills in such and such a way." "Very good; what shall we do to exterminate this bug and save our fish"? The reply was: "I don't know—haven't the faintest idea," and there we were—nearly a million of these fine fingerlings and we lost all of them but about 100,000; we dipped the dead trout out by the bushel and buried them. That is just my experience in trying to follow the old text book of the United States Bureau of Fisheries. Of course I understand that conditions do not obtain the same at each hatchery and we have worked out since some of the things that seem to be helping us, but I cannot tell you about it in a way that would be very interesting.

THE PRESIDENT: I think you will make a good member for that committee, Mr. Lincoln. Has anyone else any comments to make? I will announce the personnel of the committee after luncheon.

DR. BOST: When anything of this kind is done you have to consider where the funds are coming from; in fact we wouldn't get very far unless we did. While our present administration is spending money for conservation of every kind I believe it would be wise to appoint a small committee to see if we cannot get funds for this purpose. We have a president interested in fish; quite a few senators I happen to know are interested, and I do not see why we could not get the money so that these men can get together and compile something that will be beneficial to our hatchery men.

HOW CALIFORNIA IS MEASURING THE ANGLER'S CATCH

RICHARD S. CROKER

California State Fisheries Laboratory, Division of Fish and Game, Terminal Island, California

The need for a measure of anglers' catches is well known to us all by now. Papers read at recent meetings of the Society have brought out this fact in no uncertain way, and the discussions following these papers have indicated the general interest in the subject.

We in California have been following the preliminary work being done in other states and at the same time have made something of a start ourselves. Our diversified and intensive sport fishing, overlapping in many cases with important commercial fisheries, makes a knowledge of angling catches essential in the administration and improvement of our fish supply.

There are three general types of sport fishing in California: trout fishing in mountain streams and lakes; striped bass, salmon and black bass fishing in lowland rivers and in San Francisco Bay; and ocean fishing. Each of these fisheries is a separate problem and requires a statistical system of its own. At present we are concentrating on the latter two.

The system for collecting records was established in 1936, largely as an outgrowth of preliminary work started in 1932. It takes three forms, each of which will be discussed briefly to acquaint workers in other states with our methods.

In the first place, there is the statewide system of obtaining records from anglers themselves. This consists merely of providing places on the angling license application to list the fish caught during the preceding year. At present, purchasers of 1936 licenses are reporting on their 1935 catches. Of course, we do not expect complete returns as many anglers refuse to report and not many can remember exactly in any event. However, as samples, the applications do show us what kind of fish are taken in greatest numbers, they do show what part of the State carries the greatest burden of fishing effort, and they will show in a rough way the correlation between numbers of fish planted and caught and the relative success of different seasons. The 1935-1936 hunting license applications carried a similar questionnaire which gave very gratifying results when the entries were tabulated. Current fishing licenses are still on sale so no totals are available. Indications are that the majority of anglers are cooperating. It may be said that the success of this system depends in great measure on the license agents (sporting goods dealers, county clerks, etc.). It is up to them to insist on the applicants filling in the forms, and unless the agents have

been impressed with the desirability of good returns we will not get much in the way of results.

As with our commercial fisheries statistics and all other catch records, the license applications are handled and tabulated by means of the punched card system. With the machinery installed at the California State Fisheries Laboratory, the clerical staff can produce a greater variety of combinations and in much less time than was ever possible in the days of hand sorting and adding.

The second line of approach is concerned solely with marine fishing. Ocean angling in California, especially in the southern part of the State, has become an important industry, employing hundreds of men and affording recreation to thousands. The sport fishermen certainly take large quantities of various kinds of fish, perhaps enough to cause a drain on the supply. Consequently, the Division of Fish and Game some four years ago inaugurated a trial system for collecting angling records, as described by Clark and Croker in 1933. The early trials were for the purpose of working out ways and means for a more ambitious program which was to follow. However, the records obtained have proved to be of value for their own sake, indicating for instance that the sport catch exceeds the commercial landings of several species of market importance.

The present system, initiated at the beginning of 1936, developed directly from the early trials and is based upon the same general principles. Although it does not pretend to account for *all* fish caught by sportsmen, it does record the great majority, and more important it provides a measurable sample which will be of great aid in determining changes in the abundance of fish.

The nature of California ocean fishing lends itself readily to a statistical survey. In that respect, we are more fortunate than the authorities in other states that are attempting to measure anglers' catches by one means or another. The largest catches are made from three general types of passenger boats—charter boats, party boats and barges. These are all commercially operated boats that make a charge for fishing trips. The passenger boats plus the boats that catch bait for them dominate the pleasure fishing industry of the California coast. Although there is considerable surf fishing as well as angling from piers, skiffs and private yachts, the greatest part of the ocean sport catch comes ashore on the decks of the passenger boats, about 250 of which are in operation. The most obvious thing to do is to measure the catches of these boats, and that is exactly what we are doing.

The original plan consisted of providing selected boat operators with catch record forms to be filled out voluntarily. Operators were picked by trial and error; those who were intelligent and cooperative were encouraged, the others were forgotten. Keeping the daily catch records was extra work for the boatmen, and without continual encouragement and personal contacts, they were prone to neglect it. It soon be-

came obvious that the most important part of any system would be the "follow-up." At the time of the experiment we were not in a position to devote sufficient time to following the work through and keeping the operators interested. Nevertheless several of them continued making reports; to these people we can not express our appreciation too strongly. Their records have proved to be of considerable value, especially in the formulation of plans for the present system.

The 1935 session of the California legislature passed an enabling act under which the Division of Fish and Game is empowered to demand catch records from pleasure fishing boat operators. The law calls for the issuance of an annual permit of one dollar for each boat. The permit is revocable for failure to keep any records required by the Division. The passage of this act made possible the establishment of a full fledged program, one not dependent on the voluntary records of a handful of operators.

The system itself seems simple enough. Each operator, when he applies for his permit, is provided with a record book and a sheet of instructions. He is supposed to fill in the blanks every day and send us his reports every month. However, the system does not function quite that smoothly. In the first place, most of the operators do not come to the Division offices for their permits; they wait for the field man to find them before they bother obtaining a permit. Then, some of them object to keeping records and hours of silver-tongued oratory are necessary to persuade them. A threat of force is the last resort in the case of a few recalcitrants. After all, records kept at the point of a gun are not apt to be as accurate as those kept by a boat captain who has been convinced of the ultimate value of good catch records. At first we planned to have the operators mail their records to us monthly, but it soon became obvious that the boatmen were prone to neglect their new duty and the only way to obtain good reports was to see the operators personally and frequently, thus gaining their good will and cooperation, and at the same time collecting all records made out since the last visit. The patrol department and research staff cooperate in issuing permits and record books, in promoting the system and in collecting the reports. This first year is being spent largely in field work, getting the program started. The routine has resolved itself into seeing every operator at least once a month. As the boats sail from 20 ports at all hours of the day and night, the time consumed in making the rounds is very great. However, we expect that as soon as the boatmen become accustomed to rendering reports, we can cut down the field work a little and be in a position to devote more time to the analysis of the data. The industry already is cooperating very well and results can be considered as gratifying. After eight months of field work, we have reached the point where a number of operators are using our post-free envelopes

for turning in reports, thus relieving us of the necessity of seeing them so frequently.

As mentioned previously, we furnish the operators with forms which are to be filled in every day that the boat operates, whether fish are caught or not. Each boat receives a separate record book containing 150 pages which can be torn out whenever desired. The operators are encouraged to make their reports in duplicate and retain alternate sheets for their own use. They will then have log books of considerable value for advertising purposes (if fishing has been good) and for reference in future years. The sheets are 8 by 4 inches, the same size as our commercial record sheets for convenience in handling and filing. The following information is required: date, boat name and license number, home port, number in party fishing, and area fished. A list of the most commonly caught species with blanks for number and weight of each complete the page. Blank lines are provided for species caught infrequently. Our preliminary work showed that if the names of the various species were not printed on the sheet, the skippers would be prone to leave out the smaller fish, writing down only the larger game fish. On the other hand, with a long list of species (27 in this case), it is easy to put the number and weight on the wrong line. The name of each species is followed by the code number as used in our statistical system. Fishing areas are denoted by code numbers, as the waters of California have been divided into numbered squares to facilitate handling in the punched card statistical system. All commercial and pleasure fishing boats are provided with block area maps for their own use. Numbers and weights of fish are approximate only; we can not expect the boatmen to count and weigh all catches.

The reports give us splendid measures of the catch per unit of effort, as we can determine the number—or weight—of any species taken by a given number of fishermen using comparable gear during a definite length of time at any place in any season. The records also provide us with approximations of total catch and also of total number of sport fishermen. Because the records are just beginning to come in now, no published reports are available as yet. The apparent duplication of results from the boat records and the license applications is not a serious matter because the data are not to be used for the same purposes—one set of data is for an extensive survey, and one for an intensive study.

The third problem is the bay and river fishery of central California. Here in the delta country of the Sacramento-San Joaquin River system and on San Francisco Bay, many thousands of anglers fish for striped bass and to a lesser extent for black bass, salmon, catfish and other species. Most of the fishing is done from rented skiffs although there is a good charter boat business and a great deal of fishing from shore and from privately owned boats. Records obtained by commercial operators of skiffs and launches, although not covering all fishing, would

give a splendid sample of trends in fish abundance. Consequently, we have turned to these people for our catch reports. The State Legislature, when it passed the previously mentioned bill requiring catch records from boat operators, specifically exempted all boats on inland waters. Hence we must obtain all our data from those operators who are willing to cooperate voluntarily. This means plenty of field work and "follow up" in order to keep the operators interested. So far we have succeeded quite well and are getting reports from the operators of approximately 1,800 skiffs and 75 charter boats. The system is similar to that in use on the ocean. The boatmen are giving record books with sheets for each day's fishing. The charter boat log books are somewhat different from the ocean books, partly as an experiment to see which type is more acceptable. The skiff liveries are provided with books of a still different type, as they show not the catch of one boat but the aggregate catches of a group of boats. The skiff books are also being tried in a preliminary way on certain selected trout lakes.

The marine and inland boat records are also handled at the California State Fisheries Laboratory in much the same manner as the license applications. The reports are compiled in a variety of ways: by areas, by type of boat, by months, and by species.

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A FISH YIELD STUDY FOR CERTAIN LAKES IN THE CHEQUAMEGON NATIONAL FOREST

WINSTON A. ELKINS

U. S. Forest Service, Park Falls, Wisconsin

Clark (1934) Van Oosten (1934) and Viosca (1935), have called attention to the need for a measure of the annual fish harvest from our lakes. At the 1935 meeting of the Society several papers were presented which dealt with the problem. Eschmyer's excellent paper critically analyzed the catch from a Michigan lake. Lord's census work on a Vermont trout stream differed from the Michigan census in that catch reports were made compulsory under a "test stream law." A paper by Cunningham reported on the commercial fish yield of three Manitoba lakes. When copper sulphate was added to a Nova Scotia lake, Smith, was able to measure almost the entire fish population, but this gave no measure of the annual fish yield.

The Forest Service in the Lake States has employed a creel census modeled after that used in Michigan by the Institute for Fisheries Research. For the Chequamegon Forest in Wisconsin, fish yield studies were in progress on four lakes during the 1936 season. Two CCC boys equipped with scales, rule, notebook, census blanks, fish scale envelopes and copies of Wisconsin fishing laws were stationed at each lake. Each fisherman was contacted by the checkers after he had finished the day's fishing. The catch was weighed and measured and the census blank filled out by the checker. Scale samples were taken when the fisherman was willing, samples were obtained from twenty per cent of the fishermen checked. Scale samples were not obtainable from some of the very large specimens when the angler planned to have his trophy mounted. All of the fishermen on each lake were not checked but the number seen on each lake was recorded so that the percentage of the number checked is known. Anglers in general were found to be eager to give the desired information provided it did not require much expenditure of time and effort. The checkers who were often local experienced men soon acquired detailed and valuable piscatorial information about the checking lake.

To inexperienced anglers the checkers rendered valuable service in directing the newcomer to the better portions of the lake. Checkers were provided with lake maps and survey information to aid them in answering questions. In some cases, however, even the hydrographic map failed to convince the old timer that the greatest depth in the lake was forty-five feet and not 200 as he had fondly believed.

DESCRIPTION OF LAKES

Four lakes are included in the yield study now underway. One of these, Lake Delta, belongs to the Lake Superior drainage. The other

three, Richter, Anderson Lake, and the Pike-Round Lake Waters belong to the Chippewa River, Mississippi Drainage. Richter and Anderson Lakes are small, eutrophic, relatively fertile lakes. In late winter under a heavy covering of ice and snow there is evidence of water stratification and a marked depletion in the amount of dissolved oxygen. Tests in late March showed less than one part per million of oxygen at the bottom. In the ten feet of water at the top however, seven to nine parts per million of oxygen were present and there was apparently no hardship to the fish population as a result of unfavorable gaseous conditions. A similar condition of oxygen depletion was present in late summer, with no apparent ill effects to fish. Relatively heavy plankton growth in each lake tends to limit the growth of rooted acquatic plants to the shallower water where the sunlight can penetrate. Richter and Anderson are typically pan fish—bass lakes. A few northern pike and wall-eyed pike are also taken.

Delta Lake resembles the eutrophic type of lake but differs from Richter and Anderson in that it is entirely a spring fed lake. The water in this lake is very clear and almost barren of phyto-plankton. Potamogetons can be seen at a depth of twenty feet. The maximum depth of the lake is thirty-seven feet but at least three-fourths of the lake area supports fish food producing vegetation due to the great penetration of sunlight through the clear water. Midsummer tests indicate an abundance of dissolved oxygen and favorable gaseous conditions for fish life at all levels. Information on winter conditions are not yet available. On the basis of the yield study, Delta is strictly a northern pike, sunfish, crappie, bass lake.

The Pike and Round Lake waters, are broad, relatively shallow, wind swept lakes. As late as April 2, tests taken under the ice showed sufficient dissolved oxygen at all depths. During the summer there is complete circulation of water from top to bottom. The Pike-Round Lake waters are muskallunge, wall-eyed pike habitat, although bass are occasionally taken. Northern pike are not known to be present.

Fishing Effort

For the period of May 15 to July 29, a total of 721 anglers caught 2291 legal fish or an average of 3.2 fish per person.

The average time spent in fishing by each angler was three hours and fifty-seven minutes and it required, on the average, one hour and fourteen minutes to catch each fish. This may seem like a "long time between bites," to some but since the average poundage carried home by each angler was two pounds and six ounces, the meat value represented is not small. On the other hand, approximately forty percent of the anglers went home empty-handed.

The wide difference between fishing conditions in the four lakes is brought out in Table I. In Richter, a strictly pan fish lake, the average

angler fished two and three quarter hours, caught on the average of 4.5 fish, one every thirty-five minutes, and went home with one pound and six ounces of fish. Although not as heavily fished, conditions in Anderson Lake were much the same.

In Lake Delta, a northern pike lake with a fair stocking of pan fish, the time between bites was longer and the number of fish per angler was less but the average pounds of fish per angler was more than twice the figure for Lake Richter and Anderson.

In the muskallunge waters of Pike and Round Lakes the average angler fished five hours and thirty-eight minutes, caught on the average 1.1 fish, one every five hours and twelve minutes, but went home with six pounds and thirteen ounces of fish. Thus, the muskie fishermen who spends more time and catches fewer fish than the pike, bass and pan fish angler actually has a much larger return in pounds of fish taken.

TABLE 1. FISHING EFFORTS, RESULTS IN LEGAL FISH FOR THE PERIOD MAY 15 TO JULY 29, 1936

Lake	No. of Fishermen	No. Catching	No. of legal fish	Total pounds	Total hours	Average time each angler fished	No. fish per hour	Average time required to catch a fish	No. of fish per angler	Pounds of fish per angler
Richter	247	95	1132	377	676	2 hr. 44′	1.67	35′	4.5	1 lb. 6 oz.
Anderson	116	38	433	118	337	2 hr. 54′	1.28	46′	3.7	1 lb.
Delta	311	137	675	926	1576	5 hr. 4′	.43	2 hr. 20′	2.2	3 lbs.
Pike & Round	47	..	51	321	265	5 hr. 38′	.19	5 hr. 12′	1.1	6 lbs. 13 oz.
Total or Average	721		2291	1742	2854	3 hr. 57′	.80	1 hr. 14′	3.2	2 lbs. 6 oz.

..Record not available

Productivity in Fish

In Table II the fish production in pounds for each lake under consideration is presented for the first part of the open season up to July 29. Since the fishing intensity is apparently not at the maximum and is not the same on each lake, the figures probably do not represent maximal yield but only yield under present conditions. At least, there is no noticeable diminution in the fish supply of each lake under the present drain.

The heaviest yield per acre of water area was that of Richter Lake with eight pounds, ten ounces. This is below the yield of Lake Dauphin, which was reported by Cunningham (1935) as approximately eleven and one-half pounds per acre. This was considered a heavy yield for commercial fisheries and he reports a yield of approximately five and one-third pounds per acre for Lake Manitoba. Cunningham's figures are for the winter fishing season while the Richter Lake data applies to approximately ten weeks in early summer only. Eschmeyer (1935) estimates the total yield for Fife Lake, Michigan, to be ten pounds per acre. Since this is presumably annual yield, the productivity of Richter Lake appears to be relatively high by comparison.

Since the deeper portions of each lake are unsuitable for fishing and are known to be inhospitable to fish at certain seasons of the year due to lack of oxygen, an attempt was made to calculate the fish *producing* area of each lake. The shallow vegetation or littoral zone of each lake is known to be much richer in fish food than the deep areas. For this purpose the division point was arbitrarily set at twenty feet and that portion of each lake less than twenty feet deep was considered as the vegetation zone, and the acreage computed. By using this angle of approach the difference in productivity between Richter Lake with fifteen pounds, three ounces per acre of shoal water and Pike-Round Lake with three pounds, eleven ounces per acre, is further emphasized. The difference between the productivity of the two waters appears greater than is actually the case, however, since no correction for fishing intensity has been applied.

TABLE 2. PRODUCTIVITY FOR THE PERIOD MAY 15-JULY 29, 1936

Lake	Acreage	Acres of shoal water (vegetation zone) less than 20 feet deep	Pounds of fish checked	Per cent of Anglers contacted	Calculated 100 per cent yield in pounds	Pounds per acre	Pounds per acre of shoal water
Richter	46	26	377	95	398	8 lbs. 10 oz.	15 lbs. 3 oz.
Anderson	38	33	118	80	148	3 lbs. 14 oz.	4 lbs. 8 oz.
Delta	207	153	926	98	945	4 lbs. 9 oz.	6 lbs. 3 oz.
Pike and Round ...	1300	975	321	9	3567	2 lbs. 12 oz.	3 lbs. 11 oz.
Total	1591	1187	1742	..	5056		
Average	....	....	....	..	....	3 lbs. 3 oz.	4 lbs. 4 oz.

Methods of Fishing

Fishing from a boat was by far the most popular method on the four lakes under consideration. Altogether 581 anglers or ninety per cent used a boat as opposed to ten per cent who fished from shore.

As would be expected, still fishing was most prevalent in the two pan fish lakes, Richter, and Anderson. Sixty-three per cent of the anglers still fished while nineteen per cent were bait casters and eighteen per cent spent their time in trolling. In the pike and muskie waters, on the other hand, sixty-two per cent used the bait casting method, twenty-one per cent trolled for pike and muskie, and sixteen per cent still fished for the pan fish which were also present.

Of the types of bait in use, plugs were the most popular with 243 anglers using this type of bait while worms used by 221 anglers, minnows by 116, and spinners and flies by a few.

In the matter of fish caught, however, worms were by far the most successful with 1383 legal fish being taken by this method. On minnows 564 fish were taken and on plugs 454. Smaller numbers were taken on spinners and flies. In this case live bait is seen to be more successful than artificial bait in point of view of numbers of fish taken. Of the relative amounts of sport provided, there is no quantitative measure.

Residence, Sex and Age of Anglers

On a national forest it is important for several reasons to know the source of the forest visitors. It is likewise important in fish management to know this since the preferences and habits of the fishing public may differ considerably between states.

Early season records indicate approximately eighty-eight per cent are resident anglers and twelve per cent non-residents. The distribution of the non-residents by states is: Wisconsin 614; Illinois sixty-four; Iowa five; Nebraska six; Michigan eight; Ohio one; and California one. Illinois fishermen were the most numerous of the out of state visitors.

Lake fishing seems to be still pretty much of a man's sport. To date the men have outnumbered the women anglers almost ten to one, eighty-nine per cent of the anglers being men and eleven per cent women.

The fishing bug, also, seems to strike the adult more frequently than the young. In a sample of 687 fishermen, 544 or approximately eighty per cent were twenty years of age or over.

Muskallunge: The Pike-Round Lake waters are the only muskie waters which have been included in this study to date. Due to the large size of these lakes and the many resorts and landings, the data for these lakes are more in the form of a random sample rather than a total census.

It is interesting to note that both the striped "tiger" form and the smoother green-gray form of muskallunge are taken in Pike-Round

Lake waters. Although there is a distinct difference in coloration, the relationship of these two forms has not been settled in the literature. Green (1935) lists only the tiger muskallunge from the Mississippi watershed.

In point of view of numbers taken, plug fishing was the most successful method with fifty-eight per cent taken on plugs, twenty-seven per cent on spinners and fifteen per cent on minnows.

The average length of muskie taken was 32.6 inches with a minimum of thirty inches and a maximum of forty-two. The minimum legal length in Wisconsin is thirty inches. The fish taken ranged from seven to twenty pounds in weight, with nine pounds, thirteen ounces the average.

Northern Pike: Northern pike were taken chiefly in Lake Delta, a few were also taken in Anderson Lake and Richter Lake, they are absent from the Pike-Round Lake muskallunge waters.

Ninety-two per cent of the pike taken were on plugs, seven per cent on minnows and one per cent on spinners.

The length ranged from fourteen to forty-two inches with twenty-three inches the average. The minimum legal length is sixteen inches. The average weight was three and one-half pounds with the minimum one and one-half pounds and the maximum fifteen pounds.

Largemouth Black Bass: Largemouth bass were taken from all four lakes with the greatest numbers being taken in Delta and Anderson. Seventy-eight per cent were taken on plugs, nine per cent on worms, seven per cent on spinners, four per cent on minnows and only two per cent were caught on flies.

The range in length was from ten and one-half inches to eighteen inches. The average length was 14.1 inches, this is well above the minimum legal length of ten inches. The average weight was two pounds, six ounces with the range from one and one-half to five pounds. This is considerably heavier than the average weight of one pound, twelve ounces given by Juday and Bennett (1935) for fourteen inch bass.

Black Crappie: Crappies were taken in Delta, Richter, and Anderson Lakes. Live bait fishing was the most successful method of crappie fishing, although fly fishing for this species seems to be gaining in favor. Of 788 specimens, 440 or fifty-six per cent were taken on minnows, twenty-six per cent on worms, fifteen per cent on flies, one per cent on spinners, and one per cent on insects.

The average length of crappie checked was 7.8 inches with a minimum of six inches and maximum of eleven. The bulk of the catch is seen to be less than an inch above the legal minimum of seven inches. The average weight was 12½ ounces with a range from six ounces to one pound.

Bluegill: Bluegills were taken from Delta, Richter, and Anderson Lakes. Live bait was used almost entirely for bluegills with ninety-seven per cent being taken on worms, two per cent on minnows and one per cent on plugs.

The average length bluegill taken was five and three-fourths inches with the range from five to eight inches. As with the black crappie the bulk of the catch is seen to be just over the legal minimum which in the case of the bluegill is five inches. The average weight was nine ounces with the minimum five ounces and the maximum one pound.

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A CREEL CENSUS FROM DRY RIVER, NEW HAMPSHIRE

OSGOOD R. SMITH

Skaneateles, N. Y.

The need of accurate information on the anglers' catches from various lakes and streams has been discussed of late, notably by Clark, 1934, Eschmeyer, 1935, Davis, 1935, and Lord, 1935. Some progress has been made in obtaining this information, but to our knowledge no creel counts have been made on an unstocked stream where all the fish caught are produced by natural spawning. It is in the hope of adding some information on the harvest which may be expected from an unstocked trout stream that the following data from a one season's partial count are submitted.

During the summer of 1935 a count was made of the anglers' catches from Dry River, in the White Mountains National Forest of New Hampshire. The U. S. Forest Service stationed a C.C.C. worker on the only accessible trail to the river every day from 9:30 A.M. to about 6:30 P.M. This field man was given a letter of introduction explaining the purpose of the count and was instructed to record the number of persons and their catch for each day. Since anglers were very willing to tell what luck they had had and even to show the fish, the data secured would seem to be fairly trustworthy.

Dry River was selected primarily because the mountainous ridges confining its drainage practically force all anglers to walk in by one trail where they may easily be intercepted. The river is about ten miles long, rising on the southern slope of Mt. Washington in Oak's Gulf, and joining the Saco River above Bartlett, N. H. It is a swift mountain stream and is subject to heavy floods. The pools are excellent throughout its entire length. Most of the pools are formed by huge boulders and are connected by short cascades, but there is a short upper section where the stream is slow and meandering with a bottom of sand and fine gravel. Except in the lower two or three miles the boulders in the stream bed seem fairly stable and some of them are moss covered. A sheer fall about twenty feet high makes the upper five miles inaccessible to trout migrating up from the Saco River.

Dry River is not especially rich in food. No accurate counts were made from square-foot areas in this stream but a few such counts were made in other White Mountain streams and they all fell within the U. S. Bureau of Fisheries "Food Grade 3" (Hazzard, 1935). These grades are as follows:

> "Grade 1. (Exceptional richness) volume greater than 2 cc or 2 grams, numbers greater than 50.

"Grade 2. (Average richness) volume from 1 to 2 cc (1 to 2 gm), more than 50 organisms.

"Grade 3. (Poor in food) volume less than 1 cc (1 gm) and (or) not more than 50 organisms.

"In order to qualify in any grade *both* the number and the volume requirements must be met by the average square-foot sample."

Judging by the numbers of insects found clinging to stones, Dry River seems slightly richer in food than most White Mountain streams, but it probably would still have to be given a food grade of 3.

Brook trout were the only fish seen in Dry River. According to the stocking records of the Forest Service and the state game warden the river has never been stocked, or at least not within recent years, so we can assume that the fish taken from it are produced by natural spawning. This is locally known as a good trout stream but as in most White Mountain streams the trout usually run small. The river was open to all fishing from June 1 through August and to fly fishing during September. Our creel census unfortunately did not start with the fishing season but started over a month late, on July 8, and no count was made during the first six days of August.

The accompanying table shows the data collected. Only 1,039 trout were recorded, but since the fishing was heaviest during the early part of the summer and some allowance must be made for early July and the other days when no count was taken, 1,500 legal trout would probably be a conservative estimate of the season's harvest. This is a small catch compared with Lord's (1935) record of 8,589 trout from Furnace Brook, but since Dry River is an unstocked stream poor in food while Furnace Brook is well stocked and fairly rich in food, the comparison is not surprising. It is interesting to note that the average number of fish per angler from Dry River is 11.17, as compared to 7.2 from Furnace Brook. This higher average may be explained by the less intensive angling.

According to local anglers the fishing in Dry River in 1935 was about the same as usual so the data obtained are probably typical for that stream. The lower and more accessible part became nearly fished out well before the end of the 1935 season. This was reported to be the usual case, so it seems probable that the river is now receiving all the angling it can stand if trout production is to be maintained by natural spawning.

Much more valuable information might have been gathered if the work could have been continued for several years, but since this was not possible, it was considered that such information as was gathered should be made available.

CREEL CENSUS AT DRY RIVER, WHITE MOUNTAINS, N. H.

Date	July Fishermen	Fish	Date	August Fishermen	Fish	Date	September Fishermen	Fish
1	No count	..	1	No count	..	1	0	0
2	No count	..	2	No count	..	2	2	26
3	No count	..	3	No count	..	3	0	0
4	No count	..	4	No count	..	4	0	0
5	No count	..	5	No count	..	5	0	0
6	No count	..	6	No count	..	6	0	0
7	No count	..	7	0	0	7	0	0
8	0	0	8	0	0	8	0	0
9	2	1	9	1	14	9	0	0
10	2	12	10	0	0	10	0	0
11	2	22	11	0	0	11	3	38
12	0	0	12	0	0	12	0	0
13	2	50	13	0	0	13	0	0
14	2	0	14	4	4	14	0	0
15	1	20	15	2	3	15	0	0
16	4	15	16	1	6	16	0	0
17	2	50	17	0	0	17	0	0
18	0	0	18	4	52	18	0	0
19	2	50	19	0	0	19	0	0
20	8	120	20	0	0	20	0	0
21	4	80	21	1	11	21	0	0
22	0	0	22	0	0	22	0	0
23	0	0	23	2	23	23	0	0
24	1	5	24	6	48	24	0	0
25	0	0	25	5	41	25	0	0
26	1	24	26	0	0	26	0	0
27	2	36	27	1	8	27	0	0
28	8	97	28	0	0	28	0	0
29	5	25	29	2	23	29	0	0
30	3	40	30	3	42	30	0	0
31	3	53	31	0	0	31	0	0
Totals	56	700		32	275		5	64

Grand totals: 1,039 fish—93 fishermen.
Average catch per man: 11.17 fish.

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TAGGING NATIVE STREAM FISH

R. V. Bangham

College of Wooster, Wooster, Ohio

In the spring of 1936 with the aid of three college students, Walter Crowe, C. Byron Johnson and Lawrence Smith, a stream survey was begun in Sugar Creek. The portion of the stream selected was near Smithville in Wayne County, Ohio, six miles east of Wooster. The area was near the upper portion of the creek flowing through pasture lands and bordered by willows, other trees and overhung in many places by low growing shrubs. The water at low level varied from four to six inches on the riffles to four and one-half feet in the pools. The width varied from six to twenty-five feet and the same portion which was about one mile in length was covered each of the eleven times the stream was seined. There were many pieces of barbed wire and considerable debris in the stream when the work was started and many fish escaped because of underwater snags and large rocks. A dam, one and a half miles above the upper end of our location prevented upstream movement of fish beyond that point.

In the fall of 1935 tagged adult lake fish had been planted and the portion of the stream we covered was closed to all line fishing until July 1, 1936. We took none of these planted fish that retained their tags during the course of these studies. In addition to finding what larger fish were present we desired to see how many native fish could be recovered after being tagged and to learn something regarding the growth and movement of the fish in a limited area of the stream. There was no barrier to downstream movement and the creek was similar except the pools were somewhat wider and deeper.

The net used was six by fourteen feet with a one inch mesh and a good bag. It did not reach from bank to bank in most of the stream. The net was usually handled by two persons with a third to tag, measure and record the catch. The fish were released behind the net at the riffle where it was lifted.

The water temperature ranged from 69° to 88°F. There were no evidences of pollution in this part of the stream and the water was flowing at all times although lower on June 18 and June 25 when catches of only thirty-four and thirty-two fish, respectively, were made. Five miles below this area there was a serious source of pollution which at times during the latter part of the summer killed hundreds of fish below that point. This may have taken some of our tagged fish which moved downstream although we found no tagged fish when the area was examined at the height of the destruction.

With the exception of the fish tagged at Buckeye Lake in 1930 (Wickliff 1931 and 1933) nearly all of the fish marked in Ohio were

hatchery fingerlings or adult fish planted in the streams from Lake Erie or other Ohio Lakes. These tagged adult fish were taken near where released or downstream according to present data. When such a fish is removed from the water and the tag sent in to the Division of Conservation that prevents any more records being obtained from that individual. Very few records are available concerning movement of fresh water fish. The tags are the same as used previously in Ohio and described by Wickliff (1933) and were fastened to the gill cover. Only one dead fish bearing a tag was found but during the latter part of the survey evidences of loss of tags were apparent on several fish. Our records show the following species of fish having areas in the gill covers where tags had apparently been attached: four smallmouth bass, two rock bass, two red horse suckers, one black bullhead and two white suckers. All had their gill covers healed over and the gills were not involved but a portion of the gill cover was missing where the tag had been placed. This loss of tags is in agreement with the findings of Marcus (1933). In one case a tag was recovered in the net without the fish being captured.

In the eleven seining trips from May 8 to August 24, 1936, 1,109 fish were taken belonging to the following species numbers as follows: white sucker *Catostomus commersonii,* hog sucker *Hypentelium nigricans,* red horse sucker *Moxostoma anisurum,* quillback *Carpiodes cyprinus,* golden shiner *Luxilus cornutus,* fat head *Pimephales promelas,* stone roller *Campostoma anomalum,* carp *Cyprinus carpio,* black bullhead *Ameiurus melas,* smallmouth black bass *Micropterus dolomieu,* green sunfish *Apomotis cyanellus* and rock bass *Ambloplites rupestris.* During the first three trips in May the proportion of common shiners was high, being fifty-eight, fifty-three and fifty-two per cent of the total catch on May 8, 15 and 22, respectively. After May 22 they made up from twenty to thirty per cent of the fish taken in the net. The larger numbers were taken during the spawning period of the common shiner when they were taken chiefly in the shallow waters at the upper portion of our location. The white suckers were fairly constant in proportion ranging from twelve to twenty-eight per cent during the eleven seining periods. The hog suckers taken were from three to eighteen per cent of the catch and the black bullheads varied from one and a half to thirteen per cent, the largest number being taken on August 24 when the water was very muddy and one foot higher than normal. The rock bass were taken each trip and ranged from two and a half to twenty-one per cent, these proportions being taken in the first and last visits to the stream. The smallmouth bass range was from two and a half (obtained on the first visit) to fifteen per cent obtained August 17. The red horse suckers and green sunfish were taken in small numbers on ten of the eleven trips while fish belonging to the remaining species were taken only occasionally. The 195 fish tagged, measured and released included: fifty-seven common suckers, twenty hog suckers, fourteen red horse suckers, two carp,

twenty-one black bullheads, thirty-five rock bass and forty-four smallmouth bass. Of the number the following tagged fish were retaken in subsequent seine hauls: 26.3 per cent white suckers, five per cent hog suckers, 14.3 per cent red horse suckers, 28.6 per cent black bullheads, 28.3 per cent rock bass and 27.3 per cent of the smallmouth bass. The number of recoveries would have been higher had all tags been retained by the fish.

The following table shows the records of fish taken more than one time:

Tag No.	*Fish*	*Date Tagged*	*1st taken*	*2d*	*3d*
45413	Black bullhead	5/8	5/15	8/24	....
45406	Smallmouth bass	5/8	5/15	5/22	6/18
45402	White sucker	5/8	5/15	5/22	....
45498	White sucker	5/8	5/15	6/6	....
45428	Smallmouth bass	5/15	5/22	6/6	....
45487	Rock bass	5/28	6/6	6/10	....
45020	Smallmouth bass	6/6	6/18	7/8	....

In most instances the fish that were retaken more than once were obtained near the time of tagging. The first fish in the table was tagged on our first trip, retaken a week later and again on the last trip August 24. It was the only tagged fish taken out of the 140 obtained in the net. On the trips of June 25 and August 17, thirty-two and sixty-seven fish were taken but no tagged fish were found. One smallmouth bass bearing a tag was taken by a fisherman and the fish returned to the water but the tag number was not reported. No other reports have been obtained from line fishermen.

On August 19 a portion of Sugar Creek was seined five miles below our survey area but the records were not kept because of the numbers of dead and dying fish due to the pollution already mentioned.

If sufficient tags are retained by the fish it is our plan to continue these studies in order to record growth and movement of fish in this portion of the stream that has been studied during the present spring and summer.

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Discussion

Mr. Shetter (Michigan): I would like to ask Dr. Bangham in what manner he tagged the majority of these fish?

DR. BANGHAM: They were tagged with the little aluminum tag over the opercle. Some of them were tagged at the tail, especially the catfish.

MR. SHETTER: In Michigan before I began my studies on the trout a rather extensive experiment on the methods of application of the tag to the fish were conducted by Dr. Greeley. Dr. Greeley in his experiments with brook trout fingerlings found considerable difficulty in making the tags stay in those particular places. Members will probably recall the work in this connection of Dr. Metzlaar, formerly a member of this Society, now deceased. It was found that tagging on the opercle and on the tail was probably one of the poorest ways of doing it because the tags were dropped. I tagged my fish on the jaw because that seemed to be the place that held the tag longest; and I feel safe in saying that at least on the trout it is the most successful way of tagging.

You mentioned the tagging of black bass in your experiments. In experiments with bass in a small way here in Michigan, particularly on Wintergreen Lake, we have developed a slight variation of the jaw tagging method, namely the application of an aluminum tag to the premaxillar area and rounding it off as is done in the case of the jaw tag. I am interested to learn that another study similar to mine is being conducted, particularly in Ohio, as Ohio is my home state. I hope this study can be carried further, because it is an excellent method of obtaining information with regard to our fish.

MR. ELKINS: In work done in Connecticut in 1933, internal celluloid tags were used on brook trout and brown trout to the number of about 16,000 and thirty-four per cent were returned. I would like to ask Mr. Shetter how that compares with the returns of trout in Michigan.

MR. SHETTER: The total recovery in my tagging work on the North Branch has been approximately twenty-five per cent. We have also experimented with the celluloid tags at the Northville hatchery, but we do not use them, for the following reasons. It is my experience that a large number of Michigan anglers when they take their trout clean the fish right on the stream; they are not fully aware that any trout they catch in the stream may bear tags, and in that way a certain number of tags would be lost. I have tried to shut out all possibilities or escape of tag recoveries. Of course many of you know that all fishermen even if they do see the tag will not take the trouble to report it, and if they cannot see it, unless they know exactly where it is, that is just another recovery lost. Celluloid tags that we placed in a relatively large number of fish in the Northville hatchery did not seem to set right in the fish; from three days to three weeks later we found the tags popped out, shall I say, of the intestines of the fish. Unless they were placed exactly right in the internal organs they were lost, and several of them were picked up off the bottom of the hatchery pool. Three or four years ago, as some of the older members will recall, Mr. Cobb of Connecticut reported on internal tagging which was conducted in the state waters of Connecticut. He experienced considerable success with his recoveries, but in connection with that they conducted a lottery which created considerable public interest; a monthly prize was awarded, and it was just like a drawing. We have not had sufficient funds to do that in Michigan as a method of stimulating public interest, but we decided on this other method because it seemed to us the most logical in the light of our hatchery experiments.

DR. VLADYKOV: Did you try to estimate the local population on the basis of the number of fish that were captured without tags?

DR. BANGHAM: I have not done that as yet. We intend to continue these experiments.

MR. WICKLIFF: I would like to add that in tagging fish from Lake Erie and releasing them in our streams we found a definite downstream movement; in fact

one tag was returned a distance of two hundred miles downstream from where the fish were released. We obtained our tags from four states, including Ohio. We do not have any upstream movement at the present time. It is interesting to note that these fish seem to go downstream, but unfortunately we do not know definitely that they come back, because when a fisherman catches a fish he keeps the tag and therefore the record is lost at that particular point.

DR. THOMPSON (Illinois): I would like to ask Dr. Bangham if he has ever considered the fin clipping method. We have used that for five years at our main project to estimate the fish populations and fish cycles in the Illinois River.

DR. BANGHAM: We have considered that method, and I think perhaps we will try it, because this has not been as successful as I hoped it would be.

DR. THOMPSON (Illinois): We abandoned the tagging method because of loss of tags. With regard to Mr. Wickliff's report about downstream movement of fishes from hatcheries and from Lake Erie, in Illinois, where we caught fish, tagged them and released them on the spot, about an equal number of fish went upstream as downstream—that is, averaging over a three year period. There was no general trend either way.

DR. LANGLOIS: After considering the downstream migration of fish tagged from Lake Erie and hatcheries when they had been in comparatively quiet water, and after talking with Dave Thompson, it occurred to me it might be desirable to try to acclimatize some of these quiet water fish to current conditions before liberating them. This coming fall we will be operating a net crew in one of the reservoirs, Meander Lake, and this crew can of course make a record of any tagged fish they might get. There is a stream going down into this reservoir called Meander Creek. It is my present intention to take a batch of these quiet water fish, tag them as usual and liberate them in the stream so that our net crew will probably have a chance to recover them; then we will take another batch of the same fish and adjust them to current conditions before liberating them in order to see whether we get a difference in downstream migration as between the two lots of fish.

I recently visited a poultry farm and had a chance to see the little device which they use for tattooing their birds. Inasmuch as there is considerable difficulty involved in handling individual fish and keeping individual records by tagging, I think it would be desirable to have some method of marking an entire group of fish in such a way that records could be obtained. I wonder if anyone has ever tried this method of tattooing fish fins as they tattoo poultry.

MR. HIGGINS: Mr. R. A. Nesbitt of the Bureau of Fisheries is carrying on extensive experiments in methods of tagging, including tattooing, and he found that attempts to mark fish in mass in that way were a failure. The tattoo marks either sloughed off or faded. He used different methods, including marking with freezing and with heat and with chemical dyes, but he found none of them were permanent.

DR. GREELEY: I would like to take this opportunity of mentioning some work Dr. Embody has done on tattooing at Ithaca. I saw some trout that had been tattooed for about a year, and the marks were very legible and easy to see. There is nothing very difficult about marking trout in that way by putting a few dots of carbon ink at the base of the anal fin. The only trouble with tattooing is that it means very little to the average angler to find a trout with a few black dots on him, whereas if he sees a tag he is apt to recognize it as something out of the ordinary and take note of it.

DR. HUNTSMAN: It might be of interest to the Society to have a discussion of the significance of tagging in connection with the creel census, and I assume from

the way in which this section of the program is headed that the two are connected. We have made experiments in the tagging of salmon, and we have also been trying to get an idea of the anglers' catches. It seems as if by tagging we are able to check up on the accuracy of the creel census. The creel census was taken in nothing but a very crude fashion, because we depended upon the usual guardians of the river to collect information, and this was done for departmental work; we did not attempt to improve it scientifically. Last year, 1935, 100 fish were tagged around the first of July; we got returns of twenty-seven per cent inside of three months. We checked the creel census from the results obtained in two other ways, first, the fish caught by nets, which operate upon the fish before they enter the river—the fish were tagged in the sea—second, the fish caught for hatchery purposes. The check was very good as to the proportion of the tagged fish and untagged fish and those caught by the nets in successive weeks and those caught by the net for hatchery purposes. But when it came to the catch of the anglers we found a great discrepancy. As a result of that we came to the conclusion that the creel census was only twenty-five per cent perfect, and that there were actually four times as many salmon taken as reported. Also we were able to make a rough estimate of the population of salmon—20,000 in the sea, 4,000 taken by the anglers, 700 odd for hatchery purposes, 4,000 by the nets in the sea and 2,000 by the anglers in the river.

Dr. Harkness: In Ontario we are just starting creel census work, and we are confronted with the same difficulty that you people are who have been carrying it on for a considerably longer period. It seems to me that at the start of this work and throughout the early years it is worth our while making some effort to obtain the cooperation of the angler, and I think we can best do that by trying to convey to the angler what the basic idea of the creel census is. If we can make him understand clearly that the creel census is the final criterion of hatchery practice and fish cultural practice and really is basic to the whole problem, I believe we can get his cooperation. We have realized in Ontario that we must do as you are doing in Ohio, Michigan and other states, namely, put one or two men on each lake where we want to obtain a complete return. But at the same time we are going to impress upon the angler that he has a very definite responsibility in that respect. The reason I am particularly making that point is that a good many of our anglers come from Pennsylvania, Ohio, Michigan, New York, and so on, and we have found that there is a very keen appreciation of conservational work particularly among those coming from Pennsylvania and Ohio, but generally among those coming from the United States. Certainly they have a much keener appreciation of it than many of our own Ontario anglers. Pennsylvania has done a good job of education in that respect so far as their anglers are concerned; all the Pennsylvania people are very keen conservationists and are prepared to back us in any way they can. We do not want these people coming over from the adjacent states with the idea that their creel census work is going to be done for them, so we would be glad if you would teach them the responsibility of doing this work for us by having them do some of it for you. I think if we all get together we can bring about some useful results in that respect. We cannot do it in one year or two years, but if we take the responsibility off the anglers we will never get to the point where they will give us a return. If we try to impress upon them the fact that it is their responsibility, within ten years we might get practically complete returns from all anglers.

Mr. Eschmeyer (Michigan): We tried to contact everybody on a lake in which we were experimenting with boys from the C.C.C. camp, and people called up and complained that the boys had missed them, had seen them but had not contacted them. I think everything depends on the personality of these boys and the way they carry on. You can get cooperation if you work it right, but it is up to you; it is not up to the angler. It would seem that the only way is to get a lot of re-

prints of the literature describing the creel census and explaining what it means, and distribute them to the anglers so that they will know what is going on.

DR. W. F. THOMPSON (Washington): It may be of interest to mention some work we are doing on salt water fish, although it may not be directly applicable to your work here. We have carried on extensive experiments on halibut. For two years now we have been making comparisons of the ordinary metal tag on the opercle, the tattoo mark, and the internal body tag. I do not happen to have the figures here, but I may say briefly that the tattoo marks disappeared after the first year or became so faint that the fishermen did not notice them—I should not say they disappeared entirely, because when you look for them you find them even after a year and a half or two years. So far as the belly tags are concerned, we tested them by this method: all fish were tagged with the metal tag; half of those fish were tattooed and half of them had the belly tag in them, and we found we never got a tattooed fish back that did not have a metal tag on it—apparently no loss within the first year, at least during the time that the tattoo mark was there. However, returns from the belly tag were a very much smaller percentage than the returns from the tattoo and the ordinary metal tag. We obtained many of the fish back with the internal belly tag, but apparently the mortality was very high; the belly tag must have killed some of the fish because the returns were such a small percentage. We found great differences arising from the method by which the tattoo mark was applied. If it was just the ordinary tattoo machine that was used, making the small dots, the mark faded very rapidly, but where we concentrated on a different type of mark which put more India ink under the skin, it seemed to be more successful. But as yet we do not think it is a method that is at all comparable with the metal tag on the opercle.

MR. REID (Pennsylvania): In our state it has been a matter of perennial argument as to what type of fisherman is our main support, the sucker fisherman or the trout and bass fisherman. I prepared a query card which went out with every license, on which certain questions were asked—what species of fish do you prefer to fish for; do you prefer to fish with artificial flies, artificial bait, or live bait; are you in favor of fishing at night, and so on, and then, at the bottom, the number of fish caught of certain species. Of course that is bound to be rather inaccurate as far as creel census goes, but it was most interesting to get the views of our fishermen as to their preferences for different types of fish, and so on. The result was very gratifying to me, because I had argued that it was not the sucker fishermen that were our main support. The last time I saw the chart the bass fishermen were out in front, the trout fishermen were running a close second and those taking all other types of fish were a poor third. I thought that might be of interest in this connection.

DR. VLADYKOV: We made certain experiments with tags in fresh and salt water. Monelmetal tags did very well in either fresh or salt water; one was returned after seven years and the tag was quite clear. We also used the celluloid disc that Mr. Nesbitt used, and we found it to be very good. After two months of observations in an experimental fresh water tank we found that these tags were very clearly visible and not covered with algae, but in salt water in experimental tanks after about a month they were simply covered with algae and it was hard to tell whether the tag was white or red. I would like to ask whether anyone here has tried the tags in fresh water, and if so, whether it has been observed that the celluloid tags are readily covered with algae.

MR. SHETTER: We have not used the celluloid tags. As regards the jaw tag being covered with algae, we found that usually after about six months our tag would be covered not with algae but with a lime deposit, $CaCO_3$, which in the North Branch usually covers the rocks to a certain degree. This coating, however, can readily be broken off the tag.

DR. GREELEY: It has been pointed out that there is no 100 per cent efficient method that may be applied to all species of fish so far as tagging is concerned, although different people have had good results with different types of tags. The time element is a factor; some have had good results within a short time but found that very few tags were returned a year or two afterwards, and so it goes. Dr. Thompson mentioned good results from the tagging of halibut on the gill cover; Mr. Shetter mentioned poor results from tagging trout on the gill cover. The size of the fish may be an important factor, and there are other considerations to be taken into account. I simply wish to point out that before relying too much on statistical results obtained by tagging we ought to work out methods for each species. There is a lot of work to be done along that line.

MR. KINGSBURY (New York): We used the metal jaw tag No. 2 in some tagging we have done on bass during the last two years in ponds in the hatchery under control conditions, just to see how long the tags would hold. In the first six months out of one hundred fish tagged there was ninety-three per cent survival. At the end of the first year there was ninety-one per cent survival; at the end of eighteen months, eighty per cent. On some golden trout we tagged last fall, for the first six months there was only a seventy-eight per cent survival.

A SECOND SEASON OF CREEL CENSUS ON FIFE LAKE

R. W. ESCHMEYER

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Mich.

Last year the writer discussed the fishing for a one year period on Fife Lake, Michigan.[1] Since that time another year's census on this lake has been concluded and comparative data for fishing during the two seasons are now available. The census was taken by a crew of specially selected men from the Fife Lake C.C.C. camp under Foreman Erwin Moody's direction and was similar to the census work of 1934-5; details of the census-taking procedure are therefore omitted in this discussion. Only summer fishing, extending from June 25th to September 30th and winter fishing for the period the lake was ice-covered are here considered. It is assumed that all fishermen were seen in summer except a few (less than five per cent) who fished at night. Of those who were seen, all except ninety-one were contacted. Records for these ninety-one fishermen are not included below except in the final table where the fishing of those not contacted is regarded as having been average in every respect. All the winter fishermen were seen and contacted.

Blanks used for recording the data were similar to those used the previous year except that the items "heavy wind," "light wind," and "calm" were added under weather.

SUMMER FISHING (1935)

Data for the summer fishing are summarized briefly below.

Number of fishermen.—Census returns were obtained for a total of 3,594 fisherman-days, 2,831 for men, and 763 for women. A daily average of 36.7 persons fished the lake for the ninety-eight day period.

Number of fish, catch per hour, fish per fishermen, and average size of all fish.—The 3,594 fisherman-days yielded a total of 11,375 fish having an average length of 8.1 inches, caught at the rate of 1.27 fish per hour. The fishermen averaged 3.2 fish per day's fishing (2.5 hours per fishing day). The catch per hour varied from 2.2 the first week to 0.7 late in the season.

Analysis of the catch by species (see Table 1). The number of fish of each species caught, their average size, and the catch per hour of each species are shown in Table 1. There was considerable fluctuation in average size and in catch per hour from week to week for each of

[1] Eschmeyer, R. W., 1936. Analysis of the Game-Fish Catch in a Michigan Lake. Trans Am. Fish. Soc. Vol. 65, pp. 207-223.

Date	Smallmouth bass No. taken	Smallmouth bass Ave. size	Smallmouth bass Per hr.	Largemouth bass No. taken	Largemouth bass Ave. size	Largemouth bass Per hr.	Bluegill No. taken	Bluegill Ave. size	Bluegill Per hr.	Sunfish No. taken	Sunfish Ave. size	Sunfish Per hr.
June 25-30	83	13.5	.12	90	13.9	.13	190	7.5	.26	128	7.2	.18
July 1-7	52	13.4	.05	37	14.4	.03	207	6.8	.18	136	6.8	.12
July 8-14	91	13.3	.09	82	13.0	.08	325	6.9	.31	63	6.7	.06
July 15-21	67	12.6	.09	42	13.1	.06	341	6.7	.46	122	6.4	.17
July 22-28	29	11.6	.05	32	12.6	.05	410	7.1	.64	85	6.5	.13
July 29-August 4	47	11.6	.07	22	13.1	.03	396	7.0	.58	183	6.6	.27
August 5-11	80	13.8	.07	49	13.6	.05	647	7.1	.60	258	6.5	.24
August 12-18	135	13.3	.14	41	14.4	.04	468	7.0	.49	168	6.9	.18
August 19-25	96	14.0	.09	27	13.2	.02	428	6.9	.39	174	6.6	.16
August 26-September 1	58	12.6	.14	24	14.2	.06	169	7.3	.40	31	6.8	.07
September 2-8	9	11.9	.05	2	11.0	.01	95	6.8	.53	39	6.5	.22
September 9-15	16	14.6	.15	8	15.2	.07	4	6.8	.04	17	7.1	.16
September 16-22	17	12.0	.12	9	14.2	.06	10	7.9	.07	13	6.8	.09
September 23-30	2	14.0	.05	5	14.0	.12	6	7.5	.14	1	9.0	.02
Total or Average	782	13.1	.09	470	13.6	.05	3696	7.0	.41	1418	6.7	.16

Date	Rock bass No. taken	Rock bass Ave. size	Rock bass Per hr.	Perch No. taken	Perch Ave. size	Perch Per hr.	Walleye No. taken	Walleye Ave. size	Walleye Per hr.	Northern pike No. taken	Northern pike Ave. size	Bullhead No. taken	Bullhead Ave. size
June 25-30	618	8.1	.76	442	7.7	.62	16	19.6	.02	5	24.0	19	10.2
July 1-7	308	7.6	.27	402	7.1	.35	11	23.8	.01	4	24.3	8	9.9
July 8-14	298	7.2	.29	260	7.2	.25	15	22.5	.01	1	20.0	20	8.3
July 15-21	159	7.5	.22	100	7.0	.14	15	19.1	.02	1	24.0	..	....
July 22-28	177	7.2	.28	52	7.0	.08	28	21.3	.04	2	18.5	2	10.0
July 29-August 4	174	6.9	.26	103	7.2	.15	32	22.3	.05	5	22.8	3	12.7
August 5-11	223	6.9	.21	241	7.1	.22	21	21.3	.02	8	22.1	8	10.1
August 12-18	135	7.6	.14	313	7.1	.33	7	19.9	.01	7	23.0	6	12.2
August 19-25	166	7.3	.15	190	7.3	.17	1	25.0	tr.	4	20.0	4	10.0
August 26-September 1	46	7.6	.11	148	7.4	.35	5	18.8	.01	1	17.0	2	11.5
September 2-8	18	7.3	.10	22	6.8	.12	1	26.0	.01	2	21.5	..	....
September 9-15	6	8.3	.06	22	8.2	.21	..	....	...	5	23.4	..	....
September 16-22	39	7.8	.28	14	7.4	.10	..	....	...	6	16.5	..	....
September 23-30	17	9.1	.40	31	7.5	.72	2	16.0	.05	2	16.5	..	....
Total or Average	2384	7.5	.27	2340	7.3	.26	154	21.3	.02	53	21.5	72	10.0

[2] Black crappies were also taken. They constituted an insignificant portion of the total catch.

the various species, but the fluctuation was ordinarily not uniform. Most species were taken most readily the first week of the season. Fishing for bluegills and sunfish was best in mid-season. The catch included 782 smallmouth bass, having an average length of 13.1 inches and taken at the rate of one fish per eleven hours of fishing; 470 largemouth bass, having an average length of 13.6 inches and taken at the rate of one fish per twenty hours of fishing; 3,696 bluegills, average size 7.0 inches and caught at the rate of approximately one fish per two and one-half hours of fishing; 1,418 sunfish, average size 6.7 inches, caught at the rate of one fish per six hours of fishing; 2,384 rock bass, average size 7.5 inches and taken one every four hours; 2,340 perch, average size 7.3 inches long and taken at the same rate as the rock bass; also 154 walleyes, fifty-three northern pike, seventy-two bullheads, and six black crappies. It is understood, of course, that the data on catch per hour are based on all fishing. A person fishing for smallmouth bass did not ordinarily fish eleven hours to catch a bass. The four large game species represented 12.8 per cent of the entire catch.

Methods of fishing and kinds of bait used (see Tables 2 and 3).—Approximately ninety-five per cent of the fishermen used only one method in their day's fishing. Of the records indicating only one method sixty-nine per cent were for still-fishing, twenty-three per cent were for trolling, and eight per cent for casting. The method which yielded the most fish also yielded the smallest; the method which produced the fewest fish also produced, by a narrow margin, the largest.

Worms were used as bait more extensively than all other baits combined. They took the most fish per hour, also the smallest fish. Minnows, plugs, spinners, artificial flies and insects were used. The number of fish taken per hour by different types of baits was inversely proportional to the average size of fish taken.

TABLE 2. GENERAL DATA ON METHODS OF FISHING, FIFE LAKE, SUMMER OF 1935

Method	Repts. covering each method[2] No.	Repts. covering each method[2] Per cent	Fish taken by each method	Fish per day's fishing	Fish per hour	Ave. length of fish inches	Repts. indicating no. fish caught No.	Repts. indicating no. fish caught Per cent
Trolling	770	23	1095	1.4	0.6	11.2	383	50
Casting	281	8	339	1.2	0.5	11.3	170	60
Still-fishing	2346	69	9558	4.1	1.6	7.6	733	31

[2] This computation does not include those records indicating the use of several methods of fishing in one day or not indicating which method was used.

TABLE 3. GENERAL DATA ON EFFECTIVENESS OF VARIOUS KINDS OF BAIT USED, FIFE LAKE, SUMMER OF 1935 [4]

Bait used	No. of records	Per cent getting no fish	Hrs. per fishing day	Catch per hour	No. of fish taken	Average size of all fish (inches)
Artificial:						
Spinner	137	52	2.3	0.5	169	11.2
Plug	412	62	2.4	0.4	352	12.7
Artificial fly	25	36	1.9	1.1	53	9.4
Natural:						
Minnows	701	34	2.6	1.2	2067	8.9
Worms	1747	28	2.6	1.7	7467	7.4
Insects	14	14	3.3	1.6	77	8.4

[4] Not including those records for which no bait was listed or records indicating use or several baits in one fishing day.

Largemouth bass were most successfully fished for with plugs; smallmouth bass and perch with minnows; rock bass, sunfish and bluegills with worms; walleyes with spinner; and northern pike equally well with spinner and with minnows. Data for only the four most used baits (worms, minnows, spinners, and plugs) were utilized in making these determinations.

Relation between fishing and weather (see Table 4).—The records indicated three sets of weather conditions, with reference to clearness (clear, cloudy, rain), roughness (heavy wind, light wind, calm), and temperature (cold, mild, warm). One item in each category was checked. A large number of combinations of the nine weather conditions are possible, but data were compiled only for each condition irrespective of the others. Fish, in general, were best caught when the weather was mild, when there was a light wind and when the sky was clear. Whether fishing was best on a mild, clear day with light wind is not known since the combination of three factors may not necessarily produce good fishing even though each factor may be best when not considered in combination with the others.

The weather conditions under which each species bit best were:

Largemouth bass: Mild, light wind, rain.

Smallmouth bass: Cold, little preference with respect to wind and cloudiness.

Rock bass: Mild, calm, clear. Bit very poorly in cold weather.

Bluegill: Mild, windy, clear. Bit least in rainy weather.

Sunfish: Warm, light wind, clear. Bit least in cold weather.

Perch: Mild, light wind, rain. Poorest when cold and when calm.

Walleyes: Mild or warm, calm, clear.

Northern pike: Cold. Number taken were too few to show other preferences.

Bullhead: No preferences apparent. Number too few to permit comparison.

TABLE 4 NUMBER OF FISHERMEN, CATCH PER HOUR FOR ALL FISH AND FOR EACH SPECIES, UNDER VARIOUS WEATHER CONDITIONS, FIFE LAKE, SUMMER OF 1935

Weather	No. of fishermen	Total No. of fish taken	Hours fished	Catch per hour, all fish	Catch per hour								
					Large-mouth bass	Smallmouth bass	Rock bass	Blue-gill	Sun-fish	Perch	Walleye	Northern pike	Bull-head
Cold	68	156	174¼	.90	.04	.12	.08	.38	.09	.17	tr.	.04	.01
Mild	2,008	6,753	4,756¾	1.42	.07	.09	.33	.44	.16	.30	.02	.01	.01
Warm	1,468	4,293	3,912	1.10	.04	.08	.20	.38	.17	.21	.02	.02	tr.
Heavy wind [5]	365	1,038	886¾	1.17	.04	.09	.20	.48	.14	.19	.01	.01	.01
Light wind	1,962	5,954	4,896	1.22	.05	.08	.20	.44	.17	.25	.01	.01	.01
Calm	848	2,293	2,104½	1.09	.04	.09	.23	.39	.14	.17	.03	.01	tr.
Clear	1,929	6,354	4,897½	1.30	.05	.08	.27	.44	.17	.25	.02	.01	.01
Cloudy	1,477	4,434	3,647¼	1.22	.05	.09	.25	.38	.15	.27	.01	.01	.01
Rain	156	415	363¼	1.14	.07	.09	.25	.29	.10	.29	.01	.01	.01
Catch per hour for entire season irrespective of weather					.05	.09	.27	.41	.16	.26	.02	.01	.01

[5] Data on roughness were not recorded early in the season.

It should be understood that the estimates of temperature are with respect to summer temperature, a "cold" day is not cold in comparison with winter or annual temperature.

Comparison of fishing success of men and women.—It was reported in the previous paper that fewer women than men took no fish. The data were analyzed in greater detail for the 1935 fishing. It was found that for three of the fourteen weeks men took more fish, in proportion, than women; for two weeks both took equal numbers; during all other weeks the women caught more fish per hour than did the men. For the entire season the catch was 1.4 fish per hour for women and 1.2 fish per hour for men. The women fished for a slightly shorter average period than the men (2.3 hours and 2.5 hours respectively) but nevertheless caught more fish per fishing day.

With the exception of the last two weeks, when few people fished, the men invariably caught fish of a larger average size. It is probable that women primarily still-fished with worms while a greater proportion of men used other methods or other baits which produced fewer but larger fish. The average size of fish caught by men and women was 8.3 and 7.5 inches respectively.

Comparison of residents and non-residents.—Of the 3,594 records, 1,249 or approximately thirty-five per cent were for non-residents. The list of states and number from each state are: Ohio 596; Indiana 318; Illinois 229; Kentucky 56; Pennsylvania 44; Minnesota 3; Maryland 2; and Iowa 1. It will be noted that most of the non-residents were from three states, Ohio, Indiana and Illinois, with Ohio contributing approximately one-half of the entire number.

Residents from a large number of communities fished the lake. By approximate air-line distance the number represented in each 25 mile "zone" are as follows: 0 to 25 miles 1117; 25 to 50, 9; 50 to 75, 6; 75 to 100, 12; 100 to 125, 89; 125 to 150, 182; 150 to 175, 122; 175 to 200, 795; and 200 to 225 miles 2. It is interesting to note that with few exceptions the fishermen were either local or were from 100 or more miles away. Of the large number in the 175-200 mile zone, 704 were from Detroit. Including the non-residents, over half of the fishing on Fife Lake was by persons living over 175 miles by air-line (probably over 200 miles by road) from the lake.

The catch per hour and average size of fish caught were almost identical for residents and non-residents, the residents having a very slight advantage in both. Non-residents took approximately a third of the fish. Fishing is apparently a major factor in the tourist and resort business which is rated among Michigan's three leading industries.

Comparison of Fishing—Summers of 1934 and 1935

There were some rather marked differences in the fishing for the two seasons, especially in the composition of the catch. Whether or not

changes in the catch reflect changes in the fish population is not yet evident, but some close relationship probably exists between the two. A comparison of some of the factors is made below:

Number of fishermen.—Including the fishermen seen but not contacted, a total of 2,580 fisherman-days are recorded for 1934; 3,685 for 1935, an increase of forty-three per cent in 1935 over the previous season. This change is probably due, in large part, to an increase in the number of resorters and tourists as a result of improved economic conditions. In 1934 women accounted for 23.5 per cent of the fishing; in 1935, 21.2 per cent of the records were for women.

Hours fished and catch per hour.—Records show a total of 6,187¾ hours of fishing in 1934 and a total of 8,971½ hours in 1935. The total catch was somewhat larger in 1935, consisting of 11,375 fish as compared with 10,656 in 1934. The actual catch was almost identical for the two years since a greater percentage of fishermen was not contacted the first summer (see Table 5). The difference in total catch was not nearly so great, in proportion, as the difference in number of fishermen and number of hours fished. The total crop was slightly larger in 1935, but the catch per fisherman and catch per hour were lower during that season. The catch per hour in 1934 was 1.72, in 1935, 1.27, a decrease of approximately thirty-five per cent over 1934.

An increase of forty-three per cent in fishing accounted for an increase of less than two per cent in the total crop removed (including data for fishermen seen but not contacted). If only a very small per cent of the total fish population were caught annually, it might be anticipated that twice the number of fishermen would take, approximately, twice the number of fish. The fact that a very considerable increase in fishing failed to produce an appreciable increase in the total number of fish taken, might suggest the possibility that the lake is being fished to or beyond capacity, and that the annual crop or "take" is large as compared with the total population of fish. This is further suggested by the fact that the fish caught in 1935 averaged smaller than the 1934 fish (8.1 inches and 8.33 inches, respectively). The suggestion that the lake is overfished is so well expressed by the data, that it might easily be assumed as the truth by the "swivel-chair" investigator. An examination of the fishing, however, will show that a large number of fishermen tended to concentrate on one area of the lake, and inquiry would have revealed that these fishermen were interested primarily in catching walleyes which, though not taken frequently, were of a relatively large size. Had they preferred to catch pan fish, the number of fish taken would probably have been much greater. Each year, according to reports and, for the last several years, according to the census, the average size of the walleyes increases over the previous year, and the species appears to attract more of the anglers' attention. A decline in the catch

per hour, therefore, does not necessarily indicate that a lake is being fished to or beyond capacity.

Comparison of the catch by species.—Differences in the fish catch of the two seasons were relatively great. They may be noted by a comparison of the figures given below:

Total Number of Fish Taken

	1934	*1935*
Smallmouth bass	992	782
Largemouth bass	294	470
Bluegill	1,970	3,696
Sunfish	1,016	1,418
Rock bass	2,129	2,384
Perch	3.755	2,340
Walleye	119	154
Northern pike	48	53
Bullhead	303	72

The total number of bass taken each year was almost the same, but the number of smallmouth bass declined decidedly in 1935, while the number of largemouth bass increased decidedly. The number of bluegills almost doubled while the sunfish and rock bass each increased considerably. The perch catch dropped decidedly in 1935. The total catch of the four species of pan fish combined, increased somewhat in 1935 (8,872 in 1934, 9,838 in 1935). In both the bass and the pan fish, there seems to be some evidence in support of the contention that as one species declines another (competing species) increases. The proportion of the four large predator species combined was almost identical for the two seasons. It may be, of course, that these changes in the catch are not in proportion to changes in the actual fish population. Walleyes and northern pike both increased in the catch, but these two species were not taken in abundance either year. The decided change in the figures for bullheads may be of very little significance. Since most bullheads are apparently caught after dark, the catch is primarily dependent on the amount of night fishing for bullheads and the figures are dependent also on the percentage of night fishing reported by the census.

Average Size of Fish Taken (Inches)

	1934	*1935*
Smallmouth bass	12.25	13.1
Largemouth bass	13.5	13.6
Bluegill	7.2	7.0
Sunfish	6.8	6.7
Rock bass	7.9	7.5
Perch	7.4	7.3
Walleyes	20.1	21.3
Northern pike	21.8	21.5
Bullheads	10.5	10.0

In general, the average size for each species did not vary much. The smallmouth bass and walleyes both increased considerably, while pan

fish decreased slightly in size. The catch per hour dropped for the fish as a whole; increases and decreases in the per hour catch were, naturally, in proportion to increases and decreases in the total catch.

Methods and baits.—There was considerable variation in effectiveness of the different methods and baits and in the number of persons using them, but the two seasons agreed perfectly in one important respect; in both years the method or bait taking the largest fish took also the fewest per hour and was the least likely to take any fish at all; the reverse was true for the method or bait taking the smallest fish, and similar relationships invariably applied for methods and baits taking fish of intermediate size.

Each year most fishermen still-fished, but trolling and casting increased decidedly in 1935 as compared with 1934. Trolling and casting produced relatively similar results each year in catch per hour, but in 1934 trolling produced the fewest and largest, while in 1935 casting replaced trolling in these respects. The catch per fishing day for trolling and casting was better in 1935 than in 1934, while the catch for still-fishing and for fishing in general declined.

The use of artificial bait increased decidedly in 1935 as did the use of worms, but minnows were used less extensively in 1935 than in 1934, and this despite an almost fifty per cent increase in the fishing. Artificial flies and insects, while relatively effective in taking fish, were used by very few fishermen. For comparison the number of records, catch per hour and average size of fish for each bait are shown:

	Number of records		*Catch per hour*		*Avg. length in inches*	
	1934	*1935*	*1934*	*1935*	*1934*	*1935*
Spinner	102	137	0.9	0.5	12.5	11.2
Plug	75	412	0.5	0.4	14.5	12.7
Art. fly	10	25	2.3	1.1	8.2	9.4
Minnows	857	701	1.9	1.2	8.4	8.9
Worms	832	1,747	1.9	1.7	7.8	7.4
Insects	27	14	1.7	1.6	9.3	8.4

The effectiveness of the various baits in taking fish differed relatively little with relation to each other; all were less effective in taking fish in 1935 than in 1934. Of the four most used baits, minnows were most effective both years in taking perch and smallmouth bass. Walleyes were best taken on spinners each year. Largemouth bass were best taken on plugs in 1935, on spinners in 1934. Northern pike were largely caught on spinners in 1934 and equally well on spinners and worms in 1935.

In Table 5 certain summary data for the two seasons are listed for comparison. This table includes data for the fishermen seen but not contacted as well as for those whose records are available. It is assumed in this table that the fishing of those not contacted was average in every respect.

TABLE 5. COMPARISON OF ALL FISHING, FIFE LAKE, SUMMERS OF 1934 AND 1935 [a]

	1934		1935	
	Total Fishing	Per Acre	Total Fishing	Per Acre
Hours fished	6,676.25	8.3	9,199	11.5
Number of fisherman-days	2,580	3.2	3,685	4.7
Hours per fisherman-day	2.6	....	2.5	....
Number of fish	11,460	14.3	11,666	14.6
Fish per fisherman-day	4.4	....	3.2	....
Fish per hour	1.72	....	1.27	....
Average size of all fish	8.33	....	8.1	....
Perch				
Number	4,038	5.1	2,399	3.0
Perch per hour	0.61	....	0.26	....
Average size	7.4	....	7.3	....
Rock bass				
Number	2,289	2.9	2,445	3.1
Rock bass per hour	0.34	....	0.27	....
Average size	7.9	....	7.5	....
Bluegill				
Number	2,118	2.6	3,789	4.7
Bluegills per hour	0.32	....	0.41	....
Average size	7.2	....	7.0	....
Smallmouth bass				
Number	1,066	1.3	802	1.0
Smallmouth bass per hour	0.16	....	0.09	....
Average size	12.25	....	13.1	....
Sunfish				
Number	1,092	1.4	1,465	1.8
Sunfish per hour	0.16	....	0.16	....
Average size	6.8	....	6.7	....
Largemouth bass				
Number	316	0.4	481	0.6
Largemouth bass per hour	0.04	....	0.05	....
Average size	13.5	....	13.6	....
Bullhead				
Number	326	0.4	73	0.1
Average size	10.5	....	10.0	....
Northern pike				
Number	52	....	53	....
Average size	21.8	....	21.5	....
Walleye				
Number	128	0.15	158	0.2
Average size	20.1	....	21.3	....
Sucker				
Number	10	....	....	....
Black crappie				
Number	16	....	6	....

[a] Including data for fishermen seen but not contacted. It is assumed in this table that fishing by those seen but not contacted was average in every respect.

Winter Fishing (Winter of '35-36)

Winter fishing extended from December 1, 1935 to April 30, 1936. During this five month period 191 fishermen fished the lake for a total of 1,002¾ hours. The fishing yielded a total of 136 fish taken at the rate of about 0.14 fish per hour. The fish had an average length of 12.0 inches; the catch included ninety-four perch of an average size of 7.0

inches, forty northern pike averaging 24.0 inches long and two six-inch bluegills. Fife Lake produced, for the winter period, about one fish per six acres, a little more than one per cent of the annual "take". The winter catch was obviously too small to make any material difference in the next summer's fishing results.

Comparative data for the two winter seasons are given below. It will be noted that the catch per hour was almost identical for the two seasons; fishing was only about half as intensive during the 1935-'36 season however, as during the 1933-'34 season. Perch increased, in proportion, in the catch while northern pike decreased.

TABLE 6. COMPARISON OF WINTER FISHING, WINTERS OF '33-'34 AND '35-'36[7]

	1933-'34	1935-'36
Hours fished	2,098.25	1,002.75
Number of fisherman-days	467	191
Number of fish	286	136
Fish per hour	0.13	0.14
Average size of all fish (inches)	16.9	12.0
Perch		
Number	133	94
Average size	9.0	7.0
Northern pike		
Number	116	40
Average size	25.4	24.0

[7] A few bullheads, walleyes, suckers and shiners were also taken in 1933-'34; two bluegills were taken in 1935-'36.

General Comments

The Fife Lake census is now almost completed for the third consecutive year. During the past summer a biological, chemical and physical survey of this lake was made by one of the Institute's lake survey parties. Scale samples of a number of fish were taken for growth rate studies. Some lake improvement devices have been installed. Stocking records for the last 60 years are available. Interpretations of the data are gradually being made and it appears that, within another year or two, a few of the factors which influence the production of fish in this lake will be a little better understood.

STUDIES ON MERGANSER DEPREDATIONS IN MICHIGAN TROUT WATERS

J. W. Leonard and David S. Shetter

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Mich.

This paper is a report on findings obtained from an analysis of the stomach contents of ninety-eight American Mergansers and two Red-breasted Mergansers, collected during the late winter of 1936 in pursuance of the Merganser Control Program of the Michigan Department of Conservation.

It is generally agreed that mergansers seldom concentrate heavily on trout streams except when severe cold prevails, and ice formation drives them from their preferred feeding areas in the bays and estuaries of the Great Lakes and the larger inland lakes. Michigan's present merganser policy recommends that control measures be adopted when census work reveals a concentration of more than twenty-five mergansers per mile of stream. Such control is customarily exercised by Conservation Officers.

The authors devoted some time during January, February and March, 1936 to stream patrol in various sections of the northern part of the lower peninsula, with a view to determining centers of merganser concentration. These field observations, coupled with distributional data afforded by collections made by Conservation Officers, indicate that the large rivers support a much heavier concentration of mergansers than do the small, fast trout streams. An exception to this is offered by the Platte River, in Benzie County, where the largest single collection of recovered ducks was made. This case may well be explained by the fact that the collection was made at a point within fifteen miles of Lake Michigan. Most of the trout water patrolled by the writers in the central part of the state contained less than six mergansers per mile. These observations lead to the conclusion that when ice formation drives mergansers from the lakes they tend to settle on the first suitable open water to present itself, with the result that streams in the middle of the state are affected much less than those near the lakes. While the majority of the trout water is likely to be relatively free from mergansers, there may exist local areas of dangerous concentration.

On most of the streams which remained at least partly open, American Golden-eyes were present in large numbers. Previous work done by the Institute (unpublished) has shown that the diet of the American Golden-eye under such circumstances is made up almost wholly of roots of submerged vegetation, and of crayfish, insect larvae, and snails.

Of the 100 stomachs examined, fifty-six contained trout; thirty-three had eaten trout exclusively. The average number of trout for each of

TABLE 1.* ANALYSIS OF MERGANSER STOMACH CONTENTS

	Brown Trout	Rainbow Trout	Brook Trout	Trout sp.	Suckers	Perch	Black Bass	Other Fish	Crayfish	Frogs	Insects	Debris
Number of birds containing	20	21	8	11	6	9	1	27	18	4	5	21
Average length in inches (to nearest 0.1 inch)	8.6	6.0	6.2	4.1	4.4	2.8	4.0	2.5				
Average number per stomach	0.48	0.64	0.09	0.15	0.19	0.39	0.05	0.61	0.20	0.04	0.06	
Per cent. of total contents based on measured volume	47.4	22.5	4.9	2.8	8.8	3.3	1.0	5.1	2.1	0.8	0.4	0.9

* **Explanation of table:** All figures based on analysis of 100 stomachs, 98 of American Merganser, 2 of Red-breasted Merganser. Under the heading "suckers" are included 18 Common Suckers (C. commersonnii), and 1 Red-horse, (Moxostoma sp.). Under the heading "other fish" are included lamprey ammocoete, Rock Bass, Common Sunfish, Log Perch, Black-sided Darter, Menona Killifish, Black-nosed Dace, Lake Emerald Shiner, various unidentifiable minnows of the genus **Notropis**, Mud Minnow and Muddler. The insects include 2 phryganeid caddis larvae, a giant water bug (Lethocerus), and 3 dytiscid beetles. The frogs are apparently all the green frog, Rana clamitans. We wish to express our thanks to our colleague in the Institute, Mr. Gerald P. Cooper, for determination of the non-game fish.

TABLE 2. DISTRIBUTION OF MERGANSER COLLECTIONS, TROUT AND NON-TROUT WATERS

Date (1936)	Locality	Trout or Non-trout	Number of Mergansers	No. containing trout
Feb. 17-Mar. 8	Platte River Benzie County	Trout	36	28
Feb. 21-Mar. 1	Boardman River, Grand Traverse County	Trout	13	4
Feb. 26-29	South Branch Au Sable River, Crawford County	Trout	9	8
Feb. 24-Mar. 17	West Arm of Grand Traverse Bay, Grand Traverse County	Non-trout	7	0
Feb. 23-25	Muskegon River, Newaygo County	Trout	5	1
Feb. 18-25	Baldwin Creek, Lake County	Trout	5	2
Feb. 17-Mar. 19	Big Betsie River, Benzie County	Trout	4	1
Feb. 22	East Branch Big Creek, Oscoda County	Trout	4	3
Feb. 23	Main Stream of Au Sable River, Oscoda County	Trout	3	2
Feb. 19-Mar. 21	North Branch Au Sable River, Crawford County	Trout	3	1
Feb. 23	Middle Branch River, Osceola County	Trout	3	1
Feb. 27-29	Hatchery, Van Buren County	Trout	2	2
Feb. 21	White River, Newaygo County	Trout	2	0
Feb. 28-Mar. 1	Houghton Lake, Roscommon County	Non-trout	2	0
Feb. 29	Hatchery, Marquette County	Trout	1	1
Feb. 29	Pine River, Wexford County	Trout	1	0

the fifty-six stomachs was approximately 2.4. From Table 2, it may be seen that nine of the ducks were taken on non-trout water. Considering only those taken on trout water the percentage containing trout of all species becomes 61.04, almost two-thirds of the total. In certain instances the figure will be seen to be much higher.

It may be of interest to mention that during the peak of the merganser concentration the authors carried on extensive seining operations in the North Branch of the Au Sable, and secured almost no trout, although considerable numbers of Black-nosed Dace, Horned Dace and Muddlers were taken.

It should be borne in mind that the period of heavy merganser concentration on trout streams seldom exceeds thirty days. However, although the figures listed above would have more significance were more known about the merganser's rate of digestion, they do strongly hint that occasional local centers of merganser abundance may reach a strength definitely harmful to the trout population.

Discussion

Dr. Vladykov: I examined twenty-three stomachs of merganser from Nova Scotia. Eight stomachs from the Margaree River contained salmon parr. In other stomachs we found yellow perch, common sucker, and lake chub. In two stomachs of golden-eye only insect larvae were present. The golden-eye stomachs were taken from birds killed during the winter months.

Mr. Adams: What species of merganser do you make reference to?

Dr. Leonard: Ninety-eight American mergansers and two red-breasted mergansers.

Mr. Adams: What about the hooded merganser?

Dr. Leonard: The hooded merganser seldom appears on the trout streams. We find it on lakes in the southern part of Michigan but coming on a little later than this heavy concentration of Americans and red-breasted. I may say that a good many people confuse immatures and females of the American merganser with the red-breasted. This shows that the red-breasted is really very rare, particularly in Michigan in winter. We have had considerable experience with mergansers at the fish hatchery at Oden. From my experience with the mergansers I would say that if there is one per mile of trout stream there is just one too many.

THE DESTRUCTION OF TROUT BY FISH DUCKS

U. Sidney Beach

Milford, Michigan

During the winter of 1935-36 the three trout rearing ponds, which I have been operating for several years at Highland, in southeastern Michigan, were occupied and plundered by a considerable number of ducks. The main five acre pond had been reduced to one-half of its normal size late in November, 1935, when the onset of cold weather had prevented its complete drainage. Much of it never froze over throughout the winter, whereas all of the lakes and nearly all of the streams in the neighborhood were covered with ice. We shall confine our discussion to this one pond of which the fish population was known. Its depth had been reduced from twelve to six feet and its area halved by this partial drainage. As a result the fishes in it were considerably concentrated.

Duck Visitors

The winter of 1935-36 was unusually severe in Michigan. Lakes and rivers froze up early in December and remained frozen over until late in March. We, in southern Michigan, had not previously been troubled with mergansers. During normal and open winters the large American merganser remains on the trout streams in upper Michigan. However, late in December, 1935, the severity of the weather forced them into southern Michigan. During the winter the duck population on my fish nursery was never less than twenty each of American mergansers, golden-eyes, and mallards respectively. At times their numbers were increased by visiting flocks so that the duck population would number nearly two hundred. No attempt was made to drive the ducks away.

American mergansers are beautiful cream colored sawbill ducks. The male has a purplish head and wings with dark primaries and coverts. The female has a ruddy crested head. Both sexes have red bills and feet. Adults weigh in the neighborhood of four pounds. They are often called sheldrakes. Of the three species of mergansers frequenting Michigan the American merganser is the only one to winter within its borders. Red-breasted mergansers and hooded mergansers migrate south at the approach of winter. Mergansers are the only true fish ducks. However golden-eyes and several other species of ducks are known to live extensively on small fishes when readily available as food. This is established by Dr. Miles Pirnie in his recent publication, *Michigan Waterfowl Management*. Golden-eyes are about one-half the size of American mergansers. They are often called whistlers. They and the American mergansers were seen to dive and travel as far as two hundred feet under water. Mallards are not diving ducks and could not

have fed to any great extent on my fishes, which were for the most part in the deeper water.

Fishes Present

Previously on being filled with water during April, 1935, this five acre pond had been stocked with 383 brown trout weighing 105 pounds, fifty-one brook trout weighing fourteen pounds, and with seven rainbow weighing seven pounds. All were three year old wild fish which had been raised in this same pond. They were thus experienced in foraging for themselves. In addition 2,000 two year old golden shiners, 600 two year old chub suckers, and 200 adult bluegills had been placed in the pond. During the summer we had removed with hook and line only twenty-three brook trout, three brown trout, and eighteen bluegills. These were in superb condition. Exceedingly fine crops of fishes had been secured when the pond had been drained during March, 1933, and again during March, 1935. Approximately 2,000 pounds of fish had been secured each time. This output consisted of the pond's natural production of warm water fishes together with fingerling and adult trout, most of which had been planted in the pond. On drawing the pond I expected to remove a high percentage of the fish planted as well as a heavy crop of small warm water fishes. No losses had been noticed in the pond during the summer. When the pond was drained during March, 1936, the results given in the next paragraph were secured.

Results

Only twenty-three live brown trout remained out of the 383 planted. These were badly scarred. Six two-pounders showing injuries were found dead. Hence a total of 351 brown trout had completely disappeared. Losses from disease, unsuitable water conditions, or poaching had not occurred. Nine of the brook trout remained alive. Nineteen were missing. Not one of the seven rainbows had survived. Not a single adult golden shiner or chub sucker was to be found. Twelve of the 200 bluegills were found dead. Twenty-eight still remained alive. Several were badly scarred. In November the reduced pond had been teeming with small fishes and large trout. Yet of these small shiners and bluegills less than ten pounds survived the winter until March. I estimate that approximately 1,500 pounds of fingerlings had been lost during the winter in addition to the adult fishes already listed.

On contacting neighboring fisheries I learned that fishery stocks had been raided by mergansers at Northville, at Wolfe Lake, where a valuable stock of grayling had been entirely wiped out, and at Milford, where Mr. Striggow had lost goldfish.

Conclusions

We conclude from these results that mergansers and golden-eyes can reduce the fish population of streams, rivers, and lakes of moderate depths to almost the vanishing point. Active fish-eating birds can readily eat twice their own weight in fish each day. This is the conclusion reached by Mr. Francis Ward in England after an exhaustive study of fish predators. A flock of fifty mergansers will have no difficulty in disposing of a ton of fish in a month. They will kill fish too large for them to eat. I found several sixteen inch trout and a number of ten inch bluegills dead and dying from sawbill injuries. These birds constitute a serious fishery problem. Ponds and lakes used for holding fish over winter should be kept free from fish ducks. Their waters may be permitted to freeze over sufficiently to prevent the entrance of ducks, or the fish ducks that persist in foraging on them should be removed.

My brown trout seemed unable to cope with the fish ducks, although some of them were the largest of the fishes present. It would appear that the mergansers were able to locate and seize the brown trout while hiding on the bottom after their initial rushes to escape. In any case in view of the numbers of each species present the brown trout were more readily taken by the fish ducks than the brook trout. The brook trout is a more persistent swimmer and apparently more often escapes birds that must soon return to the surface for air.

In my ponds the brook trout is superior to the brown trout for the additional reason that it can be readily caught with hook and line, while heavy stocks of brown trout that were known to be present have invariably given poor fishing. You will note that only three out of the 383 brown trout stocked in April, 1935, were caught by hook and line, whereas twenty-three of the fifty-one brook trout planted had been taken by angling. I have never caught with hook and line over five per cent of the adult brown trout stocked in my ponds. And yet previous to 1936 the brown trout had done very well indeed. For example this five acre pond was drawn and seined during March, 1935, after a stock of 400 fingerling brown trout had been in this pond along with a heavy population of other fishes for sixteen months. I found that seventy-six per cent of this stock of brown trout had survived, and that they had increased in average length from three to ten inches during that sixteen month period.

Rainbow trout did not enter materially into this report because they have failed miserably in my ponds. Nearly all of the older rainbow caught are poorly conditioned and unfit to eat. During their first year rainbow show admirable growth, but on reaching a length of seven or eight inches they will not readily change to a minnow diet as do the other trouts. Although adult rainbows fail to sustain themselves on the natural food available in my ponds, they give the best results of any of the trouts when artificially fed.

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Discussion

Dr. Higgins: Some of you may have read an article by Mr. Pough, of the New York office of the Audubon Society, published in the *Progressive Fish Culturist* a few months ago, in which he took issue with statements which have been made as to the destructiveness of fish-eating birds and methods of control usually practised by hatchery men. If you saw this article you will recall the threatening attitude he expressed to the effect that the bird lovers of America—he representing, of course, the bird lovers—would not tolerate a wholesale program of destruction by fish culturists merely to save a few fish. He did, however, make the constructive suggestion that fish culturists who recognize the esthetic value of birds ought to undertake seriously studies for the protection of rearing ponds and hatcheries by screening, by attempting to scare the birds away or otherwise dealing with the matter without actually shooting or trapping the birds. It seems to me that is a very sound suggestion. Naturally we prefer to have birds about us, even the ones that we despise as fish eaters; they have their place in nature. But our business is to raise fish, and a solution of the problem should be found. I would like to ask whether anyone has had experience with the use of screens or scares or other means of protecting fish ponds. I suggest that anyone who has had such experience might well make some contribution to the solution of the problem; in any case many of you can give attention to it so that some practical method of dealing with it may be arrived at. I take Mr. Pough's warning rather seriously. If a widespread program of killing birds is adopted and wide publicity is given to the fact that kingfishers, mergansers, heron and so on are killed whenever they come within range of a hatchery, the hatchery men themselves will suffer from adverse publicity, because the Audubon Society with its millions of members, a potent force in wildlife conservation, should not be antagonized if there is any other solution.

Mr. Reid (Pennsylvania): We have had quite a little correspondence with Mr. Pough on this subject; I know him personally and I appreciate their viewpoint. But at the same time it seems to me they have rather signally singled out fish eating birds for federal protection. The screening of pools which has been suggested for hatcheries is out of the question because of the expense, but even if we scare the birds away or otherwise keep them from the hatcheries and allow them to become as numerous as they have become in some sections, what is the sense of raising all these fish to feed the mergansers in wild waters? I had about three hours' splendid trout fishing utterly ruined in Montana a few weeks ago by a whole flock of mergansers that swept the river in front of me, and to save my life I could not head them off. I really think we should in some way look into this merganser business a little more closely. These papers are very interesting, but perhaps we might be able to reason with the Audubon Society and persuade them at least to take the merganser off this list. As a matter of fact it is not a duck that the duck hunter shoots; he never shoots him except by accident. The hunter is out to hunt the non-fish-eating ducks, and yet the merganser that he does not hunt voluntarily is protected by federal law, thanks to the Audubon Society. I happen to be a member of the Audubon Society, although I do not agree with them in every respect, and it seems to me if we could reason with them we might

be able to convince them that there are too many mergansers running around on the trout streams and on the salmon streams in Canada, where they are eating parr by the million.

DR. HUNTSMAN: Owing to the international bird convention, Canada is working with the United States in whatever it does with regard to these birds. As a scientist I consider the proper attitude to take is not to get between the upper and nether millstones of the people who want fish and the people who want birds; we prefer simply to state the facts without taking sides in the controversy. Reference has been made to the conditions on the salmon streams; the evidence which we have obtained indicates conclusively, not for hatcheries, but for the open streams where man is not, the existence of the same state of affairs as prevails in the hatchery pond to which Dr. Beach has referred. The facts show that where those streams contain little but salmon and trout, and where the mergansers have brought up their young, there are so few fish left that they have to move elsewhere as soon as the brood comes out. The facts show that the screening of hatchery ponds will not get at the real problem at all.

MR. GRAY (Michigan): In the rearing ponds up in the international forest we were bothered quite a bit last year by kingfishers and herons, which present quite the same problem as the merganser. We attempted this year to screen the ponds by making squares with No. 9 telephone wire. For about a week this was effective in keeping the kingfishers out, but it was soon found that they would alight on the wire and go into the water from there. We also found a family of herons up the river from the ponds that disdained the wire altogether—crawled under it; so it has got to be more than wire.

DR. VLADYKOV: I had the opportunity to examine five stomachs of kingfishers, two of which, I believe, were from the Margaree River. I found only sticklebacks; I found no salmon parr or trout.

DR. HUNTSMAN: Dr. Vladykov's evidence is not as complete as that of Mr. White, who obtained kingfisher pelts from most parts of the river. He found that where there were salmon and trout, they ate only salmon and trout; where there were no sticklebacks they ate only salmon and trout, and where there were sticklebacks chiefly, then they ate sticklebacks. If it was a salmon river, they ate salmon.

OBSERVATIONS ON THE PARASITES OF THE SPECKLED TROUT IN LAKE EDWARD, QUEBEC

L. R. RICHARDSON

Department of Zoology, McGill University, Montreal

Parasitic infections of the speckled trout *(Salvelinus fontinalis* (Mitchell)) are of much interest in view of the high value placed on this species as a game fish. It is seldom that infections of this fish when it is living under natural conditions assume such serious proportions as to endanger the sporting value of a lake. This is a fact especially true in the case of lakes situated in surroundings little modified from the original wild state.

The parasitic infection of the speckled trout in Lake Edward, Champlain County, P. Q. is apparently exceptional in its severity and in all probability has contributed to no small extent to the present poor fishing at this lake. The quality of the infection is also apparently unique. The multiple adhesions of the viscera in consequence of infection of the trout by a philometrid nematode are so obvious that they cannot be easily overlooked when preparing a fish and it seems remarkable that if the infection by this parasite is wide-spread it has not come to light previously. Simon and Simon (9) have recently described a philometrid nematode parasitic in the brook trout and other hosts in the waters of Wyoming. The present specimens appear to be of a distinct species.

Of the other four parasites which I found in the trout at Lake Edward, three are apparently tolerated by the host and are occasionally recorded from trout in other waters. The fourth, the protozoan *Octomitus salmonis* Moore was recorded in only two of the fish examined and is regarded as a peculiar infection introduced into the lake. It has been fully discussed elsewhere (8).

During the season of 1935 I was able to make two visits to Lake Edward. A week was spent at the lake early in June and a second visit of twelve days was made early in October. On both occasions the opportunity was taken to visit the adjacent Lac Ecarte, a slightly smaller lake on the same watershed. Trout were also collected at the latter lake and examined for parasites.

Fishing conditions were good at Lake Edward in the early summer and twenty-nine trout were collected. Twenty-one of these fish were examined. Six of the largest ranged from 25.0 cm. to 30.0 cm. in length and weighed from three-quarters of a pound to a pound and a half. Six of the remaining eight fish were small, approximately 15.0 cm. in length and belonged to a group of 4,000 yearlings which had been planted in Lake Edward in May, almost exactly a month prior to my

first visit. These fish were identifiable by the damaged condition of the fins and by varying degrees of "bull-headedness" present in consequence of their having been raised in a hatchery. These irregularities permitted the ready distinction between the fish of this group and those of a similar size which had been spawned in the lake.

Of the fish in this group, the ones which were examined in the early summer were already infected by the acanthocephalan *Echinorhynchus lateralis* Leidy, common in the Lake Edward trout at this time. Two were also infected by an unidentifiable Diphyllobothriid larva. Four others from the same group were examined in the fall and found to be similarly infected. In only one case a slight infection by the philometrid nematode was recorded.

The other twenty-one fish examined in the early summer were heavily infected. Two were infected by *Octomitus salmonis* Moore as well as by other forms. These were both adult fish. Three were infected by cestode larvae in addition to the other forms, *Crepidostomum fausti* Hunninen and Hunter was present in the gut of fourteen. *E. lateralis* was present in all the fish in this group. The philometrid nematode was present in seventeen fish. Approximately sixty per cent of the fish were infected by three of these parasites at the same time. These were fish of 25.0 cm. and more in length. Only three fish showed a quadruple infection.

The condition in the trout from Lac Ecarte was quite distinct from that in the trout taken at Lake Edward. Of the six fish from the former taken in June, five were parasitised. These were infected by *Eubothrium salvelini* (Schrank). Only one was heavily infected. A few specimens of *C. fausti* were taken from one of these fish.

Very few trout were taken in the fall. The four specimens belonging to the group introduced into the lake in May and which were taken again in the fall have been mentioned above. Two other small trout, 12.0 cm. and 20.0 cm. in length, and an adult male were taken at this time. The smallest was free from parasites. The second fish was slightly infected by the philometrid nematode and by the plerocercoid larva. The adult male, 28.0 cm. in length, was most heavily infected by the philometrid nematode and by the same plerocercoid larva.

Twelve adult trout were taken at Lac Ecarte at this time. These fish were all heavily infected by *C. fausti* and *E. salvelini.* The larval cestode was present in a few of the fish, the adult was found in all.

The food of the trout taken at Lake Edward in the spring was relatively uniform. The trout of all sizes were feeding principally in shallow water, chiefly on the pupae and emerging adults of the common caddis-fly, *Phryganea cinerea.* A few amphipods, *Hyalella knickerbockeri* (Bate) were eaten by the younger fish which had apparently been feeding in the shallow water steadily since several of the stomachs also contained leeches (*Nephelopsis obscura* Verrill and *Herpobdella punctata* (Leidy)). Planktonic algae and a few fragments of terrestrial

insects were recorded. The trout taken at Lac Ecarte were feeding principally on sprawling dragon-fly nymphs and on chironomid and caddis-fly pupae.

In the fall a greater variety of food was recorded. Large planktonic organisms were commonly represented and shared an almost equal representation with a variety of insect larvae and some few terrestrial forms. One stomach was entirely filled with balsam needles! A single trout taken at Lake Edward was found to have eaten a small smelt (*Osmerus mordax* (Mitchill)). The smelt in Lake Edward are heavily infected with the microsporidian *Glugea hertwigi* Weissenberg but although the trout feed on the smelt there were no indications of the transmission of the parasite to the larger fish.

The measurements given for the several species in the following descriptions are taken from preserved material.

The writer wishes to express his gratitude to the management of the Laurentian Club, Quebec, for practical assistance in the field and for the many courtesies which they so liberally extended to him and without which the present collections could not have been made. The examination and study of material have been carried on in the Department of Zoology, McGill University, and the writer is indebted to Dr. H. B. Fantham, Chairman of the Department for his valuable criticism. The presence of the problem was brought to the writer's attention by Mr. B. W. Taylor, Director of Fish-Culture for the province of Quebec.

CREPIDOSTOMUM FAUSTI Hunninen and Hunter 1933, Fig. 3:

The present specimens from trout taken at Lake Edward in the early summer are generally small, ranging in length from 0.54 mm. to 0.78 mm. The smaller specimens are immature. Only an occasional specimen reaches a length of 1.0 mm. The subterminal oral sucker is surmounted by six obtuse lappets and is obviously smaller than the acetabulum. The pharynx is ovoidal. The short oesophagus bifurcates anterior to the genital pore. The latter is crowded between the forking of the gut and the anterior border of the acetabulum. The crura are long and reach beyond the posterior testis. The heavy vitellaria meet behind the posterior testis and extend anteriorly into the pharyngeal region. The testes are large, subequal and almost completely fill the post-acetabular field between the vitellaria. The cirrus-sac is cylindrical. The ovary is concealed. The uterus is small and contains only a few eggs, twelve to fifteen. The eggs average 0.052 mm. in width and 0.064 mm. in length. The two eye-spots, situated one either side of the back on the dorso-lateral aspect just anterior to the middle of the acetabulum are prominent in unprepared specimens.

Large numbers of this trematode were obtained from the upper two-thirds of the intestine of fourteen of the twenty-one trout taken at Lake Edward in the early summer. The infected fish ranged in length from 17.0 cm. to 30.0 cm. Other uninfected fish were taken at the same time and from the same localities. The latter fish were small and ranged

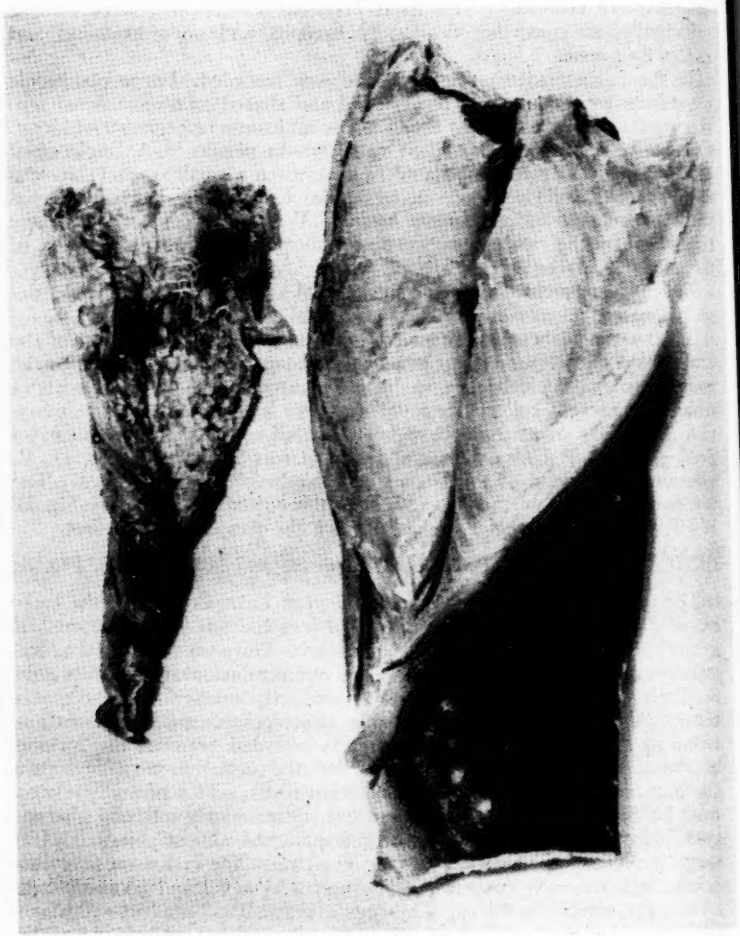


Figure 1. The visceral mass produced in adult speckled trout following infection by a philometrid worm. On the right, the mass in situ; on the left a similar mass opened and showing the adult worms and cysts.

from 12.0 cm. to 22.0 cm. in length. The larger fish which were taken were all infected. Yearling trout which had been placed in the lake a month previous to their capture and examination, were not yet parasitised and fish from the same group examined in the fall were also found to be uninfected by *C. fausti.*

Of the six adult trout taken at Lac Ecarte in June only one was slightly parasitised by this trematode. The others were not infected. The twelve adult fish taken in the fall were all heavily infected. This is the reverse of the findings at Lake Edward, where although only two large fish could be examined in the fall both were found to be free from infection by this form. This apparent distinction between the seasonal peak of infection at the two lakes is difficult to reconcile, and although the number examined at Edward in the fall is small it would still appear that a variation is present. This may be due to the more severe general parasitism of the trout in Lake Edward. Van Cleave and Mueller (12) have recorded that in the case of the closely related *C. solidum* Van Cleave and Mueller 1932, parasitic in the perch of Oneida Lake, the peak of infection occurs in the fall and the parasite is very scarce in the early summer. This contrasts with the case of *C. fausti* at Lake Edward but agrees with conditions at Lac Ecarte.

The speckled trout appears to be quite tolerant of *C. fausti.* A heavy infection by this form even when coupled with a heavy infection by the trout tape-worm *(E. salvelini)* is unproductive of obvious injury. The infected trout taken at Lac Ecarte in the fall were heavily infected by both these forms, but were spawning fish in excellent condition and showing a good color.

C. fausti and *C. solidum* are closely similar species and distinction between the two is at first difficult. This is especially so in view of the compactness of the organs and the general opacity of the body shared alike by both species. In consequence, the study of whole preparations is difficult and unsatisfactory with regard to the details of the internal organisation. A study of serial sections is necessary for the complete definition of many important characteristics. The two species may be readily distinguished by means of the acetabulum, which is relatively larger in *C. fausti* than in *C. solidum.* There is no difficulty in distinguishing *C. transmarinus* (Nicoll, 1909) from both of the preceding species, *C. transmarinus* being much larger, flatter and more translucent than either of the other two species.

In connection with the present work I have been able to locate and re-examine five of the slides prepared by Stafford. The records of *C. laureatum* (equals *C. farionis* O. F. Muller of present date) published by Stafford (10) have been commented upon by students of this genus. Nicoll has already pointed out that the material described by Stafford was of a species distinct from the European *C. farionis,* and Hunninen and Hunter (2) have recently described similar material from New

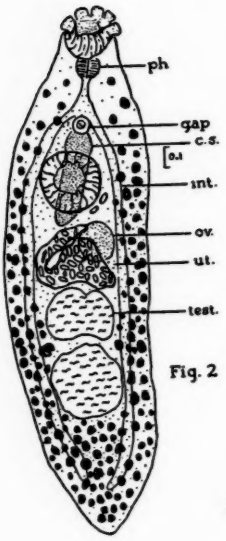


Fig. 2

Fig. 3

Fig. 4

Fig. 5

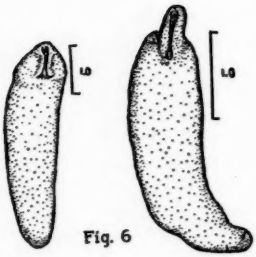
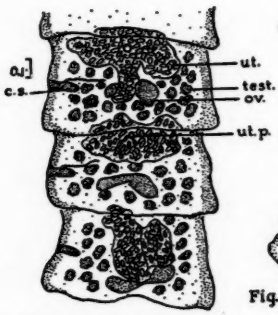


Fig. 6



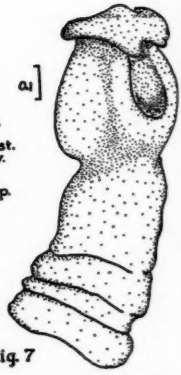


Fig. 7

Figure 2. *Crepidostomum transmarinus* (Nicoll), drawn from a specimen collected by Stafford at St Andrews, New Brunswick.
Figure 3. *Crepidostmum fausti* Hunninen and Hunter, collected from the intestine of an adult trout taken at Lake Edward, Champlain County, P. Q.
Figure 4. *Crepidostomum solidum* Van Cleave and Mueller, drawn from a specimen collected from a perch by Stafford.
Figure 5. *Eubothrium salvelini* (Schrank) egg, and hooklet from the embryo.
Figure 6. Diphyllobothrium larvae sp. inq., specimens removed from cysts on the wall of the stomach of an adult trout taken in the fall.
Figure 7. *Eubothrium salvelini* (Schrank), scolex, and mature proglottids of an abnormally well-extended specimen.

York State in confirmation of Nicoll's views, under the name of *Crepidostomum transmarinus* (Nicoll, 1909), the equivalent of the latter's *Stephanophialia transmarinus* the name given by Nicoll to the form described by Stafford.

In publishing his records of this trematode under the name of *C. laureatum,* Stafford lists as hosts the perch, the doré and the speckled trout. He had remarked the distinction between the material he obtained from the perch and the doré and that from the trout, and noted that this was almost so great that the former were of separate specific standing from the latter. Of the five slides which I have located, three are preparations of *C. transmarinus* (Nicoll) from trout taken at St. Andrews, New Brunswick and also in the vicinity of Montreal. These specimens are quite typical and range in length from immature specimens 0.8 mm. in length to mature adults 2.5 mm. in length. The remaining two slides are preparations of *C. solidum* Van Cleave and Mueller, 1932 collected from perch taken in the vicinity of Montreal. The latter number about twenty specimens in all and range from 0.8 mm. to 1.1 mm. in length. To emphasize further Stafford's confusion of these forms, four of the slides are labelled *Bunodera nodulosum* the species with which he noted he had originally confused the material. Figures 2 and 4 are drawn from Stafford's preparations of these species.

EUBOTHRIUM SALVELINI (Schrank, 1790) Figures 5 and 7:

The present material is composed of small cestodes, the largest being only 90 mm. in length and 2.0 mm. wide at the largest proglottid. The short scolex is 0.5 mm. in length, and is sub-rectangular in lateral view. The two bothria are strong and deep. The scolex is surmounted by an obvious terminal disc the margin of which is indented above each bothrium. The reproductive organs appear first in proglottids about 10.0 mm. from the scolex, the first egg-bearing proglottids being 15.0 mm. from the anterior end. The genital cloaca is marginal, situated at the middle of the segment and tends to be unilateral but occasionally changes to the opposite side in several segments. The uterus is large and somewhat bilobed in appearance. The uterine pore is median and anterior, situated so far forward on the proglottid that in normally unexpanded segments it is concealed by the posterior margin of the immediately anterior segment. The ovary is bilobed. The vitellaria are moderate in number and scattered, but restricted from the marginal fields. The testes are numerous, the cirrus sac short and practically oblong in dorsal view. The ellipsoidal eggs measure 0.068 mm. to 0.092 mm. in length by 0.048 mm. to 0.080 mm. in width. The contained larva has six hooklets (Fig. 5).

Following the work of Nybelin who critically examined the European *Abothrium crassum* and has shown it to be a complex of seven species, Wardle (13) and Kuitunen-Ekbaum (4) have examined cestodes from speckled and other trout taken in northern and western Canadian

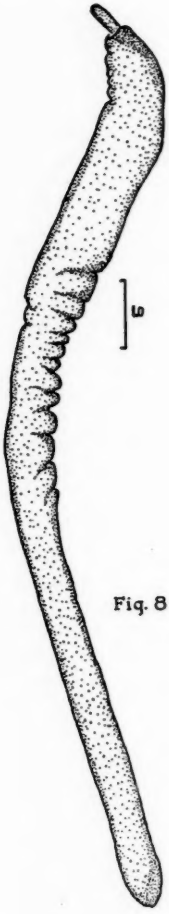


Fig. 8

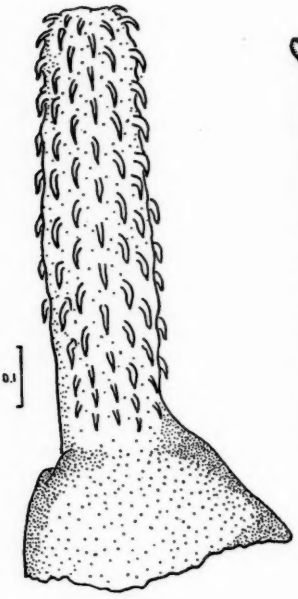


Fig. 9

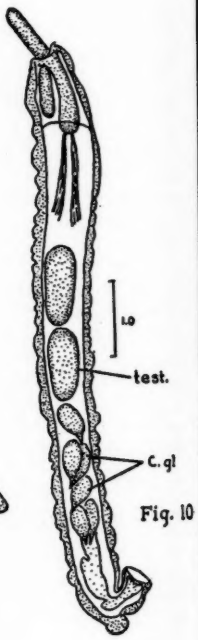


Fig. 10

Fig. 11

Figure 8. *Echinorhynchus lateralis* Leidy, external view of adult female.
Figure 9. *Echinorhynchus lateralis* Leidy, proboscis of adult female.
Figure 10. *Echinorhynchus lateralis* Leidy, structure of adult male, drawn from a specimen stained with picro-carmine and mounted in balsam.
Figure 11. *Echinorhynchus lateralis* Leidy, egg from an adult female, drawn from an unprepared specimen mounted in water.

NOTE: All scales are expressed in millimeters.
C.gl., cement glands; C.s., cirrus sac; G.ap., genital aperture; Int., intestine; Oes., oesophagus; Ov., ovary; Ph., pharynx; Test., testis; Ut., uterus; Ut.p., uterine pore.

waters, and have shown this material to correspond with the European *E. salvelini*. Kuitunen-Ekbaum has examined and compared the Canadian material with Nybelin's original preparations of this species and has established the common identity of the material from both countries.

It is customary to find that, as at Lac Ecarte, the majority of the adult trout in a contaminated water are heavily infected. In the worst cases so many worms are present that the lumen of the gut in the pyloric region appears to be blocked. Even in such cases the trout do not seem to be affected by the presence of this parasite and are apparently fully tolerant to it. This is not the case with other species of trout. Wardle (13) records an almost epidemic mortality amongst the young of *Salvelinus alpinus malma* in western Canada, which he attributes to a heavy infection by this cestode.

Infection of the trout in Lake Edward by *E. salvelini* was slight. One trout of the twenty-one examined in the spring was infected by the adult worm. The trout at Lac Ecarte were heavily infected. Six trout from the latter lake which were examined in the early summer and also twelve adult trout taken in the fall were all, with the exception of one female, heavily parasitised. The worms were present in the pyloric portion of the gut, the majority resting with their scolices attached in the pyloric caeca.

In all probability it will be found on re-examination of the material that many of the previous records of *Abothrium crassum* occurring in speckled trout are based on the present species. Under the older, inclusive name Cooper (1) has recorded the presence of cestodes in speckled trout at Harietta, Michigan, and recently Hunter and Hunter (3) have stated that practically twenty per cent of the speckled trout taken in northern New York State were infected. The latter writers point out that this worm was found in trout taken from lakes, and that the trout taken from streams were free from infection by this form.

DIPHYLLOBOTHRIID LARVA Species Inquirenda, Figure 6:

In many cases a light infection by a plerocercoid cestode larva was noted in trout taken from Lake Edward. The larvae were contained in cysts attached to the outer surface of the stomach, and more rarely on the other organs. The cream colored cysts are subspherical to ovoidal in form and have an average diameter of 2.0 mm. to 3.0 mm. They contain white plerocercoid larvae 3.0 mm. to 5.0 mm. in length and 0.75 mm. to 1.0 mm. in width. The body is flattened in the plane of the bothria so that the thickness of the specimens is only a quarter of their width. The posterior end is often bluntly rounded, or more rarely equipped with a short spherical appendage. The anterior end is most commonly in the form of a low triangle with a bluntly rounded apex, or more rarely it is elongated. The bothria are 0.75 mm. in length, their apertures reduced to a slit. The anterior end is often invaginated, and the slits of the bothria being then in opposition appear continuous. In the latter condition

the anterior end appears to be incised by two deep, narrow grooves with sharp edges and set at right angles one to the other.

I have also obtained specimens showing these characteristics from the gut of *S. fontinalis*.

Wardle (14) lists seven records of Diphyllobothriid larvae from Canadian fishes. These forms have been found free in the gut and on the coelomic surfaces, or imbedded in the liver of various salmonoid fishes, but as in the present case no definite assignation to the adult species has been possible.

The twenty-one trout examined in the early summer and which had been taken at Lake Edward showed only a slight infection by this larva. Only two cases were recorded and in each only a few larvae were present. The results with the fish taken from Lac Ecarte were similar. Of the six yearling trout which were taken within a month after their introduction to Lake Edward, two had already become infected with these larvae.

Slight infections were recorded in the case of the twelve trout taken at Lac Ecarte in the fall, and also in the 20.0 cm. specimen from Lake Edward taken at the same time. The adult male, 28.0 cm. in length, taken at Lake Edward in the fall was most heavily infected. Cysts literally covered the entire surface of the wall of the stomach, and actually concealed the surface from view. They were associated with many cysts of the philometrid nematode.

It was suggested that the multiple visceral adhesions present in the adult trout taken at Lake Edward might be the result of infection by this plerocercoid form, as in the case of the similar injury to the smallmouth black bass (*Micropterus dolomieu* Lacapédè) caused by the presence of the plerocercoid larvae of *Proteocephalus ambloplitis* (Leidy) in the coelomic cavity. It is doubtful that this is so in the present case owing to the absence of similar adhesions in the infected trout at Lac Ecarte, and the generally light nature of the infection in the trout at Lake Edward.

THE NEMATODE INFECTION, Figure 1:

Of the parasites found in the trout at Lake Edward, the one productive of most serious damage to the host was a philometrid nematode of the genus *Philonema.* At the present time, this genus contains only two species, *Philonema onchorynchi* Kuitunen-Ekbaum, 1933 from the peritoneal cavity of *Onchorynchus nerka* (Walbaum) and *Philonema agubernaculum* Simon and Simon, 1936 from the peritoneal cavity and muscles of *Prosopium williamsoni* (Girard), *Salvelinus fontinalis* (Mitchill) and *Salmo shasta* (Jordan). The present specimens appear to be of a third species which I tentatively name *Philonema salvelini.*

The collection made in the spring consisted principally of mature females heavy with eggs and larvae. Males were relatively scarce. The single adult male examined in the fall yielded many young females and

males, and also a large number of encysted immature specimens ranging from 4.0 mm. to 20.0 mm. in length. Many dead adult worms were found in the body cavity of this trout and some dead adults in a few of the larger cysts.

Encysted forms have been found on the liver, stomach and other organs, and in the mesenteries supporting the gut and gonads. The cysts are readily recognisable. They are either cream or faintly reddish in color, characteristically flat and measure up to 5.0 mm. in diameter. The wall of the cyst is thin, and the contained worm can be seen through it. The flatness of the cysts enables them to be readily distinguished from the cysts of the Diphyllobothriid larva also present in some of these trout.

The infection was found to be heaviest in the adult fish. Seventeen of the twenty-one taken at Lake Edward in the spring were infected. The parasites were found in specimens 20.0 cm. and more in length, and infection is severe in fishes more than 22.0 cm. long. In the group taken in the spring it was recorded that every trout exceeding the latter size was parasitised by this nematode.

In the smaller fish no apparent injury was noted and only a few worms were collected from each. In the larger trout the presence of the worms causes adhesions of the viscera (Fig. 1) and in severe cases the entire contents of the abdominal cavity are bound into a solid mass by multiple adhesions of the peritoneum and of the mesenteries. These adhesions not only bind the organs together but also attach the mass of the viscera to the body wall. The condition of the viscera resembles that described by Hunter and Hunter (3) and others in the smallmouth black bass and other centrarchids following infection with the plerocercoid larva of the bass tape-worm (*Proteocephalus ambloplitis* (Leidy)). On breaking through these adhesions and separating the organs, many adult and young worms of both sexes are found. The worms are situated in cysts, in sacs and in open chambers. The latter represent the remnants of the coelom between the viscera. The largest number of worms is usually found in the fold of the duodenum and amongst the pyloric caeca. In the earliest stages of infection the adhesions are restricted to the gut where they bind the stomach, spleen, pyloric caeca and intestine into a single mass. Later stages also have the liver included into the mass, and in the most advanced cases the whole bundle is attached to the body wall.

Of the fourteen female trout examined in the early summer, one was egg-bound. The wall of the oviduct was greatly thickened and attached firmly to the other viscera. The wall had lost its natural transparency and was almost opaque. The oviduct contained eggs of full size, but these were of poor color, brittle and hard to the touch.

The six trout which had been planted as yearlings in the spring and were examined a month later showed no signs of infection by this worm. Only one of the four trout belonging to the same group which was taken

and examined in October was already infected, but not markedly so. The latter fish was a female, 18.0 cm. in length.

In spite of the severity of the infection and the condition of the viscera in the larger trout, these fish showed no external indication of their condition, but could be distinguished from similar but uninfected trout from Lac Ecarte in having the head slightly larger in proportion to the more elongate and slender body than in the trout from the latter lake.

REDESCRIPTION OF *ECHINORHYNCHUS LATERALIS* Leidy 1851, Figures 8 to 11:

The present specimens collected from the gut of trout taken at Lake Edward agree well with the brief descriptions given by Leidy (5) and augmented in later publications. A full account is given in the posthumous publication of his researches (Leidy Jr. (6)). Van Cleave (11) in his recent study of Leidy's collection was unable to locate the specimens from which the descriptions had been taken and owing to the relative incompleteness of the data given by Leidy it was found necessary to set aside the species as being one of doubtful significance.

Leidy's original material, seventy-six specimens from the gut of *S. fontinalis,* was collected by the late Professor Baird. Baird visited and collected fish in New York State and Quebec, and it is quite probable that the acanthocephala described by Leidy under the name of *Echinoryhnchus lateralis* came from this vicinity.

In the present specimens the body is cylindrical, bluntly rounded both anteriorly and posteriorly. In the adult female the anterior portion of the body is frequently slightly swollen, but not to such a pronounced extent as in *E. leidy,* the anterior end in *E. lateralis* being only 1.0 mm. in width and the posterior end 0.75 mm. The female is 10.0 mm. to 14.0 mm. in length. The proboscis typically points obliquely to the longitudinal axis in the female and may even be nearly at right angles to it. The proboscis is 0.75 mm. in length, cylindrical and armed with eleven or twelve circular rows of hooks, each row containing six hooks. The hooks are alternate in arrangement. The hooks of the terminal circle are weak; of the next row, smaller than those of the middle rows. The former are 0.032 mm. to 0.040 mm. in length; the latter 0.036 mm. to 0.048 mm. long and with a basal piece of almost the same length. The hooks of the last two or three basal rows are weak and only 0.028 mm. long. The lemnisci are moderate, being one-half to three-fourths the length of the proboscis receptacle.

The males are 6.0 mm. to 7.0 mm. in length and 0.7 mm. to 0.9 mm. in width anteriorly. Posteriorly they are only 0.5 mm. to 0.6 mm. in width. The testes are rarely contiguous, subequal in size range in length from 0.7 mm. to 1.0 mm. and have a diameter of 0.3 mm. to 0.4 mm. The ratio of the length of the posterior testis to the anterior testis is as 10 : 11. There are six pear-shaped cement glands arranged essentially in a linear fashion but showing considerable variation from an almost

moniliform arrangement with only two of the glands paired to a pattern where the first gland is single; the second, third and fourth in an aggregation; and the fifth and sixth paired or single. A common pattern is one where the first gland is single; the second and third paired; the fourth, single; and the fifth and sixth glands paired. The most anterior cement gland is seldom in contact with the posterior testis which lacks a contact face. The copulatory organ is most frequently invaginated.

None of my specimens reached a maximum length of one inch as described by Leidy.

The embryos when removed from the gravid female are 0.088 mm. to 0.112 mm. in length by 0.020 mm. in width. The middle shell of the embryo forms polar prolongations which are distinctly longer than wide.

The present species differs from *E. leidy* Van Cleave, 1924, which it most closely resembles in size, by having fewer hooks on the proboscis, a more slender form and less slender eggs. It differs from the European *E. truttae* Schrank, 1786 in having fewer hooks, and from *E. salmonis* Muller and the closely related *E. coregoni* Linkins in having fewer hooks in the circular rows and a greater length to the mature adult. The eggs are also larger than in the latter species (Cf. Meyer (*7*)).

E. lateralis was present in the gut of every trout taken in the early summer at Lake Edward. The parasites were numerous, even in the smaller trout. In the case of the yearling trout which had been in the lake for only one month, it was found that these fish had already become infected when they were taken and examined in June. In the latter fish the infection was obviously recent and the majority were immature worms from 5.0 mm. to 13.0 mm. in length. Worms of the latter size were rare and not gravid. The stomachs of many of these yearling fish contained amphipods, *Hyalella knickerbockeri* (Bate). It is probable that this is the secondary host of the present parasite, since this was the only species of amphipod found at the lake.

Summary

An account and descriptions are given of the parasites found during the course of a study of the speckled trout at Lake Edward, Champlain County, province of Quebec. These include *Crepidostomum fausti* Hunninen and Hunter, *Eubothrium salvelini* (Schrank), *Diphyllobothrium larvae* species inquirenda, a philometrid nematode of the genus *Philonema,* and *Echinorhynchus lateralis* Leidy. The latter species is redescribed. A sixth parasite, *Octomitus salmonis* Moore has been accounted elsewhere.

The degree of parasitism of the fish at this lake is severe and a comparison is made with the condition found in the speckled trout at an adjacent lake, Lac Ecarte, on the same watershed. At the latter lake, the trout were infected only by *C. fausti* and *E. salvelini.*

The presence of the nematode in the peritoneal cavity of the adult speckled trout results in the formation of multiple mesenteric and peritoneal adhesions which bind the viscera into a compact mass similar to that produced in certain centrarchids by the plerocercoid larva of *Proteocephalus ambloplitis* Leidy. A case of an egg-bound female trout is recorded, the egg-binding resulting from the condition of the viscera.

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PARASITES OF WAYNE COUNTY (OHIO) STREAM FISH

R. V. BANGHAM

College of Wooster, Wooster, Ohio

One hundred and five fish belonging to sixteen species were taken from three streams, Killbuck, Sugar and Salt Creeks and examined for parasites. Of this number sixty-four or 64.9% of the fish examined were infested. This is approximately the same percentage of infestation as found by Bangham and Hunter (unpublished data) in a study of parasites of Lake Erie fish but the number of parasites carried by the individual Lake Erie fish was higher. The number of larval encysted parasites in the visceral organs was higher and there were more species of infesting forms found for the lake fish.

In most of the cases the parasites caused but slight apparent damage to the host. The so-called "grubs," *Clinostomum marginatum*, were not numerous enough to cause great harm. The larval trematodes belonging to the family Strigeidae were found usually in small numbers. The majority of parasites were flukes taken from the digestive tracts of the hosts. Four species of larval flukes were found and ten species of adult flukes contrasted to three of cestodes, two of nematodes, two of acanthocephala and one species of leech. More species than this are often encountered on one kind of fish from lakes. For black bass from lakes in Ohio there has been reported, (Bangham 1933) the following number of parasites: twelve flukes, five cestodes, four nematodes, two acanthocephala, three parasitic copepods and one species of leech.

The following list of sixteen species of fish shows the number examined and infested with the number of different forms of parasites found:

PARASITES OF WAYNE COUNTY (OHIO) STREAM FISH

Species of Fish	*No. Examined*	*Parasitized*	*No. species Parasites*
Quillback *Carpiodes cyprinus*	1	1	1
White sucker *Catostomus commersonii*	14	3	2
Hog Sucker *Hypentelium nigricans*	6	2	2
Red Horse sucker *Moxostoma aureolum* ..	3	1	1
Common shiner *Luxilus cornutus*	9	9	3
Stone roller minnow *Campostoma anomalum*	3	3	1
Black bullhead *Ameiurus melas*	13	10	4
Trout perch *Percopsis omiscomaycus*	3	2	1
Brook stickleback *Eucalia inconstans*	8	6	1
Smallmouth black bass *Micropterus dolomieu*	20	17	9
Green sunfish *Apomotis cyanellus*	5	4	2
Blue gill *Helioperca incisor*	2	0	0
Warmouth bass *Chaenobryttus gulosus*	1	1	2
Rock bass *Ambloplites rupestris*	12	3	5
White crappie *Pomoxis annularis*	3	0	0
Johnny darter *Boloesoma nigrum*	2	2	2
	105	64	

The following list gives the parasites found with their host fish. The degree of infestation is not given because it was not heavy except in the case of some of the smaller flukes:

Flukes

Allocreadium ictaluri Pearse, black bullhead
Alloglossidium geminus (Mueller), black bullhead
Clinostomum marginatum (Rud.), Smallmouth black bass
Crepidostomum cornutum (Osborn), Smallmouth black bass and rock bass
Crepidostomum cooperi Hopkins, warmouth bass and green sunfish
Crepidostomum isostomum Hopkins, trout perch
Crepotrema funduli Mueller, brook stickleback
Cryptogonimus chyli Osborn, smallmouth black bass and rock bass
Lebouria cooperi Hunter and Bangham, common shiner
Neascus ambloplitis Hughes, smallmouth black bass and rock bass
Neascus vancleavei (Agersborg), stone roller, common shiner and rock bass
Neascus sp. (external cysts), Johnny darter, common shiner, hog sucker
Rhipidocotyle papillosum (Woodhead), smallmouth black bass
Triganodistomum simeri Mueller and Van Cleave, common sucker, hog sucker

Cestodes

Bothriocephalus claviceps (Goeze), smallmouth black bass
Corallobothrium fimbriatum Essex, black bullhead
Proteocephalus fluviatilis Bangham, smallmouth black bass, rock bass

Nematodes

Agamonema sp., Johnny darter, green sunfish
Camallanus oxycephalus Ward and Magath, smallmouth black bass, warmouth bass

Acanthocephala

Octospinifer macilentus Van Cleave, white sucker, red horse sucker
Neoechinorhynchus crassius Van Cleave, stone roller, quillback

Leeches

Piscicola punctata (Verrill) smallmouth black bass, black bullhead, green sunfish

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1933 (1934) Parasites of the spotted bass *Micropterus pseudaplites* Hubbs, and summary of parasites of smallmouth and largemouth black bass from Ohio streams. Trans. Amer. Fish. Soc. 63: 220-228.

AN AIR BLADDER DISEASE IN LAKE TROUT FINGERLINGS*

LOUIS E. WOLF

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Mich.

The air bladder of fish does not seem to be particularly subject to infection. Davis devotes only one brief paragraph to this organ in his *Care and Diseases of Trout,* mentioning a roundworm which has been reported in the air bladder of wild salmonids. The standard German reference (Plehn, 1924) mentions several sporozoan and worm parasites found on or in the air bladders of fish, but they do not seem to occasion any great mortality in their hosts. One paragraph in Plehn's book is, however, particularly pertinent to the discussion which follows and is worth quoting in full (page 427):

> "In a general infection caused by *Bacterium cyprinicida,* the causative organism of red plague (Rotseuche), there can occur an infection of the air bladder and a thickening of its wall. The inside of the bladder then contains a creamy mass which consists of a bacterial culture—sometimes a pure culture. Probably other bacteria can also produce similar effects."

The disease to be described here occurred during the winter of 1934-35 at the Rome, New York fish hatchery, and was confined to small lake trout fingerlings averaging about 3 cm. in length. The fish were 63 days old from the time of hatching and had been feeding 38 days when the investigation was started. Mortality had started rising about a week before this and continued quite high for about three weeks. The loss was distributed throughout all the troughs containing lake trout but did not spread to any of the brook or brown trout which were at that time in troughs at the same hatchery.

It was a peculiar circumstance that the larger fish contracted the disease to a greater extent than the smaller. Diseased individuals sank to the bottom of the trough where they rested quietly until they died. While the disease was at its peak almost every fish taken from the bottom of the trough showed the typical symptoms.

Dissection of diseased specimens showed that the air bladder was more or less deflated in all cases, usually containing no air whatever. Thus diagnosis did not even require the aid of a microscope. The shrunken stub of an air bladder could easily be removed, and when macerated and examined under the microscope a teeming mass of motile, rod-shaped bacteria was observed. These bacteria were found to be particularly numerous in the mass of loose connective tissue surrounding the air bladder and could always be obtained, often in pure culture, from this tissue.

* Investigation made while employed by New York State Conservation Department.

Laboratory facilities for a positive identification of the bacterium were not available, but the organism proved to belong to the fluorescent group and was tentatively identified as *Pseudomonas fluorescens.*

In figure 1 a normal air bladder is shown in cross section. The wall consists of a cuboidal epithelium surrounded by a thin layer of dense connective tissue. Beyond this, and filling the space between the peritoneum, kidneys, and body wall, is a mass of very loose connective tissue. Figure 2 is a cross section through the same region in a diseased fish. It can be seen that the epithelium lining the lumen of the air bladder is columnar, and that much more connective tissue is present around the bladder.

A structure present in all the diseased specimens sectioned was a posterior opening in the air bladder. In figure 3 this opening is shown in cross section and in figure 4 in longitudinal section. It will be seen that the high columnar epithelium which lines the inside of the air bladder continues through the posterior opening and lines a portion of the outer surface of the bladder surrounding the opening. The peritoneum is unbroken, so that the air bladder does not communicate with the body cavity. It merely opens into the region of loose connective tissue dorsal to the peritoneum. This loose tissue is the substance which was found to contain such a rich culture of bacilli. Its disintegrated condition in the region of the posterior opening is evident in figures 3 and 4.

In the absence of a series of specimens showing the progress of the disease through various stages, we can only speculate as to its course. Since the pneumatic duct remains open in the salmonids it might be supposed that this would afford a chance for bacteria to wander into the air bladder from the oesophagus just as they sometimes do into the human appendix from the intestine. Since *Pseudomonas fluorescens* is a common water bacterium, not ordinarily pathogenic, it might get into the air bladder rather frequently but cause no particular disturbance there. With the presence of a posterior opening to the bladder, however, this organism could pass through into the loose connective tissue surrounding the structure and there set up a pathological condition resulting in a proliferation of connective tissue and failure of the bladder to expand. The posterior opening alone might prevent the bladder from expanding, even in the absence of a restricting excess of connective tissue.

It is hard to imagine the posterior opening as being merely a structural anomaly. Thousands of fish died from this disease, which did not occur the previous year nor the year following although lake trout eggs from the same source (wild fish from Raquette Lake, New York) were hatched at this same hatchery all three years. Neither did it occur that same year among fingerlings from the same source which were hatched and reared at another hatchery. But if the opening was caused by bacteria, why was the disease confined exclusively to the lake trout?

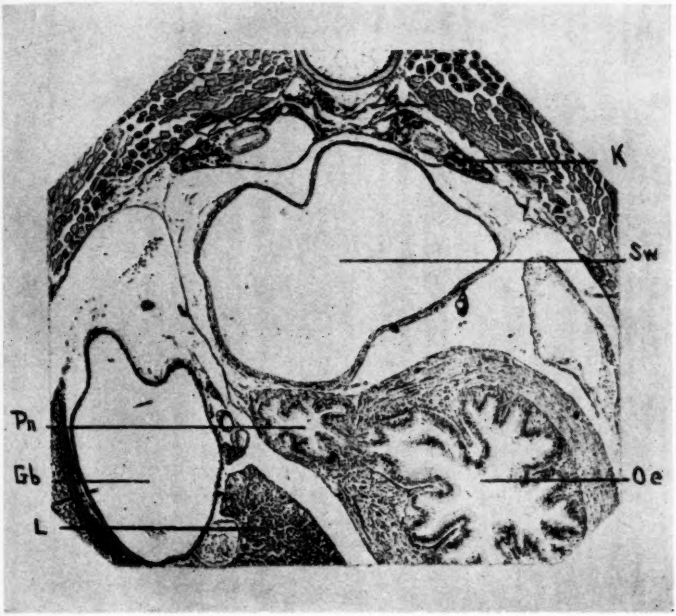

Fig. 1. Cross section through normal air bladder of 30 mm. lake trout. x 38.

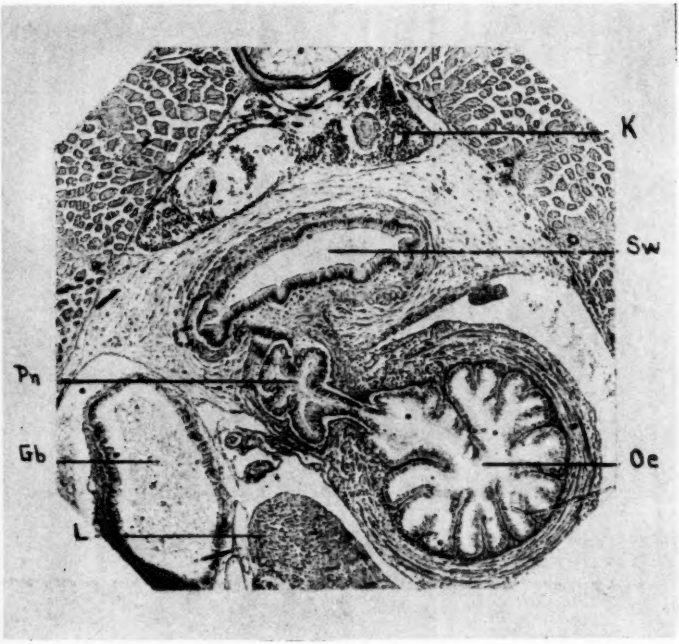

Fig. 2. Cross section through diseased air bladder of 30 mm. lake trout. x 38.

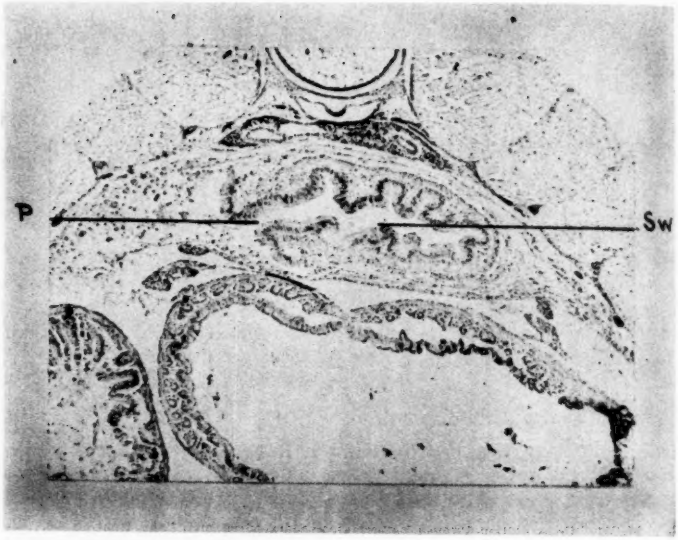

Fig. 3. Cross section through diseased air bladder, posterior region, showing the posterior opening. x 38.

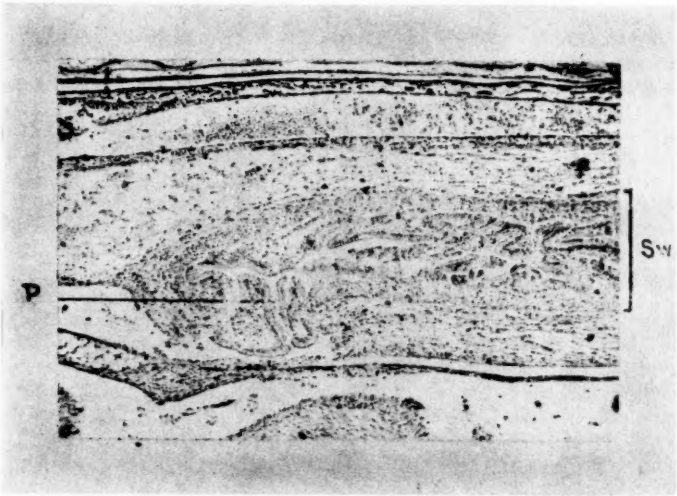

Fig. 4. Longitudinal section through posterior half of diseased air bladder showing posterior opening. x 38.

Does the lake trout air bladder have some pecularity near its posterior end which makes it more susceptible to bacterial attack?

No treatment was discovered for the disease. Salt baths were started before the nature of the infection was known, but these had no noticeable effect. The disease finally subsided and the survivors were normal healthy fish. Whether any of the survivors had recovered, or whether the disease is always fatal is not known.

The author is indebted to Mr. Harry Faber of the Consolidated Water Co. of Utica, New York for placing at his disposal a bacteriological laboratory and for assistance in bacteriological work.

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Explanation of Figures

Gb	Gall bladder	P	Posterior opening of air bladder
K	Kidney	Pn	Pneumatic duct
L	Liver	St	Stomach
N	Notochord	Sw	Air bladder
Oe	Oesophagus		

BASS TAPEWORM INFECTION IN A REARING POND

T. H. Langlois

Chief, Bureau of Fish Management and Propagation, Ohio Division of Conservation, Columbus, Ohio

Two hundred wild adult smallmouth bass were transferred on May 12, 1934, from Lake Erie to pond No. 6 at Ohio State fish farm No. 7 A, located at Piqua, where twenty of them died from injuries caused by handling. The remaining 180 began spawning almost at once, because the Piqua pond waters were considerably warmer than the waters of Lake Erie, and a total of 206,082 fry were obtained from them within the next few weeks. These results were considered satisfactory at the time they were obtained.

The 180 breeders yielded only 74,756 fry in the spring of 1935. The 145 breeders that survived were transferred from pond No. 6 to another pond before the spring of 1936 to permit the use of pond No. 6 for rearing purposes. In this other pond they yielded 91,300 fry in 1936. No difficulties have been experienced with the young in this pond, but the overflow waters from pond No. 6 go into pond No. 1, and the 20,000 smallmouth bass fry placed in pond No. 1 on May 18, 1936 were so heavily infested with plerocercoid larvae of the bass tapeworm *(Proteocephalus ambloplitis)* that they were planted on July 6—in the ground.

The infection was discovered by Supt. Jacob Guenthner, who noted full rounded bellies on the fish but knew that they were not eating or growing properly. When the fish were removed for burial, many of them were preserved in formaldehyde, and examination of these revealed a direct relationship between length of fish and number of larvae present. The following figures illustrate this point.

Total length of fish (Millimeters)	*No. of fish*	*Average No. of larvae*
27-31	1	67.0
32-36	10	40.1
37-41	11	24.8
42-46	10	14.3
47-51	7	10.6
52-56	2	19.0

Hunter and Hunter (1928, Suppl. 18th Ann. Rept. N. Y. Cons. Dept. p. 202) state that the mature proglottids, when passed by the adult bass, scatter the eggs before settling to the bottom, and that the eggs must be picked up inside of 48 hours by the first intermediate host. The known first intermediate hosts are three species of *Cyclops,* one of *Macrocyclops,* one of *Encyclops,* and the amphipod, *Hyalella knickerbockeri.*

Negative results were obtained from attempts to infect experimentally *Daphnia pulex*, and the authors imply in the following statements (Ibid., pp. 206-7) that *Daphnia magna* is also a non-carrier. "At present all indications point to the advisability of wiping out the copepods and replacing them with some type of food which cannot carry the larval stages of the tapeworm. That this may be the practical solution of the problem is indicated by the successful production of fish food in various parts of the country. The U. S. Biological Fisheries Station at Fairport, Iowa, and Dr. G. C. Embody of Cornell University are working on this problem while the state hatcheries at Pratt, Kansas and Hackettstown, New Jersey have large daphnia producing plants in operation."

In the present instance it appears probable that *Daphnia magna* served as the first intermediate host, because this species has been cultured in the Piqua ponds for three years and were present in dense brown clouds in pond No. 1 when the bass were of sufficient size to feed upon them.

Ground carp flesh was offered to the fish in this pond beginning June 8. It has been noted before that bass grow faster when eating fish flesh than when eating water fleas. The probable explanation of the fact that the larger young bass contained fewer cestode larvae than the smaller ones is that the larger ones shifted earlier to a diet of ground fish and avoided further infection and thus outgrew their fellows.

Discussion

Dr. Bangham: In one of the hatcheries where this infestation arose I was able to trace the fish from the hatchery into the stream, when they had been planted there, by the result of the infestation, because the stream bass did not get the larval infestations. Sometimes when they escaped from lakes near the entrance to the lake the fish had it, but not further up. Also there was one lake in Ohio where the infestation was equal to that in this hatchery pond.

Dr. Davis: During our bass rearing experiments at the Fairport station a number of years ago we had an instance which exactly paralleled that of Dr. Langlois. However, this may be explained in another way. In this particular instance the fish in one pond were found to be heavily infested with the same parasite, much more so than in any other pond. While I do not recall the exact size of the fish, I remember that the average length of the fish in this particular pond was only approximately half of that of the average fish in our other pond, although they were approximately the same age. In this case the fish were not fed with artificial food; they were relying entirely on the natural food produced in the pond, and there was no evidence that there was any less food in that pond than in any of the others. So the evidence in that case indicates clearly that the stunted growth of the fish in this pond was due to the heavy infestation of tapeworm and not to the difference in food.

Dr. Langlois: My reason for suggesting the explanation I did rather than the one offered by Dr. Davis is that in 1927 I examined the entrails of a number of smallmouth bass from several different locations in Michigan, including the north end of Lake Michigan, north end of Lake Huron, Lake St. Clair, Douglas Lake—a small inland lake near Mackinaw in the lower peninsula—and Gilead Lake in the lower part of the lower peninsula. I made extensive counts—although I never published these—of the number of *Proteocephalus ambloplitis* taken out of these bass; my attempt at that time was to see if there was a correlation between the extent of infection and the size and growth of the bass. I found,

contrary to expectation, that the heaviest infection occurred in the largest and best of the bass. My idea at that time was that the explanation was found in the fact that for the bigger bass the food conditions were better where the optimum conditions prevailed for infection. I may be mistaken, but because of that experience I made the other explanation here.

DR. DAVIS: Of course at the time we found the bass were heavily infected it was too late to make any further study as to the cause of infection; this was discovered only when the ponds were drained in the fall. The ponds were not overstocked; there was nothing noticed during the season to indicate that there was any less food in this pond than in any of the others. The only difference I could find at that time was that the fish in this pond were much more heavily infested than those in any other pond. It was also quite noticeable in this instance that the larvae were often found in the liver.

DR. LANGLOIS: In this case the larvae were not in the liver but in the mesenteries or very close to the outside of them, and an incision down the body wall revealed the larvae at once.

DR. BANGHAM: The larvae grow a good deal faster in the liver, and do more damage there.

THE INTRODUCED LARGEMOUTH BASS, A PREDATOR UPON NATIVE CUBAN FISHES

LUIS HOWELL RIVERO

Museum Comparative Zoology, Cambridge, Mass.

During recent years the Cuban Government has imported, among other fish species, several hundred largemouth bass *(Huro salmoides* Lacépède) for direct introduction into Cuban waters and for propagation purposes. Many of the fish were introduced into the fresh-waters near Habana, and introduction into other localities on the Island also was made. The principal object of these introductions was to increase the supply of fishes suitable for human consumption. In introducing the largemouth bass into Cuban waters, however, no forage fishes or other foods for the bass were introduced, and as a consequence these game fishes were forced to feed upon native fish species and other native forms of life.

The *Cyprinodontes* or top-minnows form a large proportion of the total number of species of the exceedingly small fish fauna of Cuba. These cyprinodonts are of small size and were readily available to the bass, and as a result they formed in most instances the principal food of this introduced species. Unfortunately, the drain upon the cyprinodonts by the bass has been too great, resulting in a decrease in the population of these small fishes in most of the localities inhabited by the bass.

We are well aware of the value and importance of many of the carnivorous species of cyprinodonts in mosquito control work. Many of the species of *Gambusia,* for instance, have been of tremendous value and importance in mosquito control work due to their feeding habits. The food consists primarily of aquatic insects among which great numbers of mosquito larvae and pupae are included. These fishes are particularly important in southern countries where they assist in holding in check, and reducing the numbers of the malaria-carrying *Anopheles* mosquito. With the decrease in the cyprinodont population, due to the introduction of the bass, the numbers of mosquitoes have greatly increased in recent years, accompanied by an increase in the amount of malaria. Conditions became so acute that the Rockefeller Institution, through its International Health Service, has recently delegated several medical doctors for field research work on the control of malaria in Cuba.

Research experiments upon malaria control indicated that one of the most effective measures in combating malaria, in those waters where the bass occurred, was to kill, by poisoning, these introduced fishes. In poisoning the waters all other native fish species were also killed. After

the bass had been removed, propagated cyprinodonts were introduced into these waters. The small fishes have increased, and the abundance of mosquitoes is now being held in check.

The effect of the bass upon the native fish fauna in many Cuban waters was revealed at the time these waters were poisoned, for it was found that in many instances a few large cichlids *(Cichlasoma)* were all that remained of the native fish fauna. These cichlids were too large to be eaten by the bass, and the only food left for these two species appeared to be crabs and shrimps.

To summarize: the introduction of largemouth bass in certain Cuban waters, where fish food is limited and native fish species few in number, has resulted in the partial or complete eradication of the native cyprinodonts, and subsequent increase in malaria, the malaria-carrying mosquito and other mosquitoes; it has not, as was hoped, provided a new and abundant source of food; and it has finally necessitated the destruction of the bass in order that cyprinodonts may again inhabit the waters where they formerly occurred and again hold the mosquitoes in check.

BLOOD CLOTS IN THE GILLS OF TROUT*

LOUIS E. WOLF

Institute for Fisheries Research, Michigan Department of Conservation, Ann Arbor, Mich.

During the summer of 1935 the author had an experience with a gill disorder in brook trout (Wolf, 1935) which differed in its external symptoms from that described by Davis as well as from that more recently recorded by Fish (1935).

In mild cases the chief symptom was a sticking together of the gill platelets, or lamellae, so that the outline of the filament appeared smooth. Though no sections were cut of gills in this condition the cementing substance appeared to be slime and not epithelial tissue as in the disease described by Fish.

In more advanced cases the gills appeared congested, and blood clots were visible in the platelets. These clots were very distinct in freshly killed specimens and the larger ones could easily be seen with the naked eye. In many cases the gills were thickly sprinkled with clots, and among fish in this condition mortality was quite high.

Figure 1 shows a section through two diseased filaments. A comparison with the figures presented by Fish shows that the difference between the two diseases is quite distinct. The lamellae are, for the most part, clean—the preservative and treatment connected with sectioning having removed the slime from between the platelets. There is no such excessive proliferation of epithelial tissue as is shown in Fish's figures. Instead, the characteristic structure is the blood clots in the lamellae. These clots, the result of a clogging of the capillary, swell some of the platelets to many times their original thickness. Sectioning revealed a tremendous number of small clots which had not been visible in a gross examination of the gill.

Whether the appearance of blood clots and the comparative absence of fusing and clumping of neighboring filaments is enough to distinguish this disorder from those described by Davis and Fish is open to question. However, another difference appears in the response of the disease to treatment. In common with the disease described by Fish, no benefits were derived from copper sulphate treatments—in fact, quite the reverse. One-minute dips in 1:4000 potassium permanganate solution were beneficial. But ten minute-baths in three per cent salt solution, administered five days in a row, were most successful of all in checking the mortality. These treatments were conducted in troughs. When salt treatments were tried in ponds they were not at all effective in checking

* Investigation made while employed by New York State Conservation Department.

the disease. That the beneficial effect was due to the salt, and not merely to the clean water in the troughs, was shown by the fact that a check group placed in a trough and not treated had a high mortality throughout the experiment.

No bacteriological study of the diseased gills was attempted, so nothing is known as to a possible bacteriological cause.

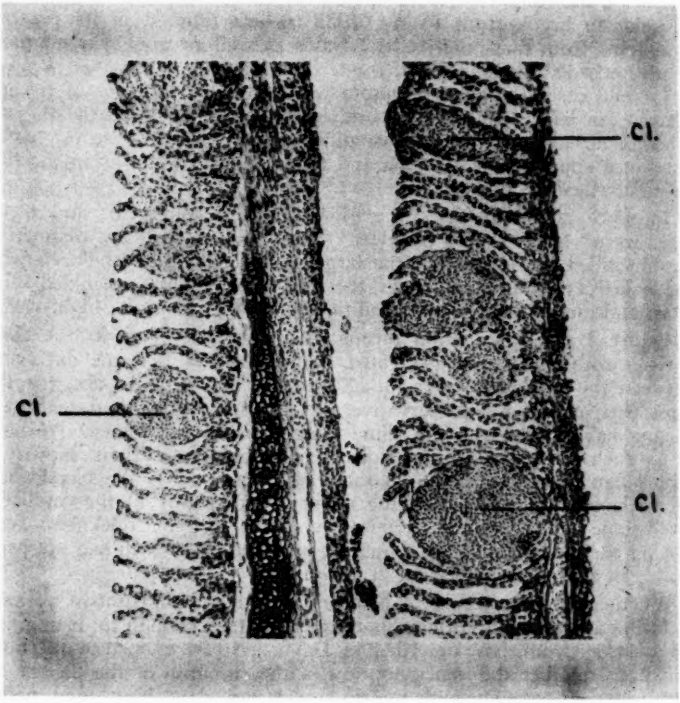

Fig. 1. Showing blood clots in the gills of trout.

Conclusions

1. A gill disease of trout is described which is characterized by the appearance of blood clots in the gill lamellae.
2. This disease responds well to repeated treatments in three per cent salt solution, provided the fish are held in clean troughs. Treatments in ponds were unsuccessful.
3. The bacteriological aspects of the disease have not been studied.

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Discussion

Mr. Wolf: The title I have given this paper is a rather clumsy one, but I did not know whether I had a new gill disease here or not. I had some correspondence with Dr. Davis and he mentioned that he had seen blood clots in connection with some other disease; so I am not sure that this is a specific disease, but if it is its name will have to be the gill disease that the man from Michigan talked about at the Ann Arbor meeting.

Dr. Davis: It has been my experience that blood clots on the gills are really quite common. They are due to a number of different factors. In many instances they appear to be due primarily to an irritating agent of some sort; that is the case with the ordinary gill disease which is so common in the east. Also I have seen it occur where the gills are infected with protozoa of various kinds. It is quite prominent in the gills of fish infected with furunculosis. Is there a possibility, Dr. Wolf, that furunculosis could have been involved in this instance?

Dr. Wolf: I think not. We have cultured blood from fish in that hatchery and got no signs of furunculosis.

Dr. Davis: There is nothing in the blood clots themselves to indicate furunculosis, but it is a common thing in fingerlings infected with furunculosis; it is very noticeable. In connection with the disease found in the lake trout, was that bacterial infection of the fish confined to the region of the air bladder, or was it found in other parts of the body cavity?

Dr. Wolf: No, it was confined to the tissue immediately surrounding the air bladder.

Dr. Davis: You have nothing to indicate the cause of the posterior opening?

Dr. Wolf: No. I sectioned six normal fish and six diseased fish, and all the diseased fish had the posterior opening.

BREEDING AND FOOD HABITS OF THE PIKES, *(ESOX LUCIUS AND ESOX VERMICULATUS)**

FRED MCNAMARA

Howell, Michigan

The following observations on the pike were made in a marsh area adjacent to Lake Chemung, Livingston County, Michigan, from 1933 to 1936 during the spawning season in April.

The breeding localities of the two species of pike are usually remote from the natural habitat of the adult fish. In fact, a part of the area in which material for this report was gathered was one mile from the lake. The marsh in which spawning takes place is merely a catch basin for the drainage of the local cultivated lands and usually dries up in late spring or early summer, depending upon the rainfall. Part of the marsh has been, in recent years, under cultivation during the summer. The adult fish reach this marsh by means of a small creek.

Vegetation consists largely of bulrushes and marsh grasses which grow very profusely. The bottom is covered with leaves and decaying plant debris which has accumulated in years past. Dense growths of maple trees are also present.

In the spring when the ice begins to leave the lakes and streams the pike begin their spawning migrations. They congregate along the shore of the lake near the mouth of the stream, and when the ice is completely out of the stream and broken up on the edges of the lake the migration begins. The time of first migration in the Lake Chemung area is from late February to the middle of April.

The very first fish to proceed up the stream are the males of *E. vermiculatus*; they are followed by the males of *E. lucius*. In both species the males are followed by the females. As the spawning season reaches its height, the averages size of the males and females of *E. lucius* increases. The female which is the larger in both species usually enters the marsh in company with one or more males.

Very often when several males are with a female of *E. lucius* a fight ensues. The males dive at one another and apparently nip each other until some are driven away and the one or ones that remain continue on with the female. A female not yet ready to spawn often fights off the attentions of the males until she has found a favorable place and is ready to accept their attentions.

From my observations I am inclined to believe that pike have some sort of a sense of smell because I have seen a female wander over the

* This paper was originally to have appeared under the joint authorship of the late Professor T. L. Hankinson and myself. The study was undertaken at his suggestion and with his most able help.

marsh followed a few minutes later by a male along practically the same route that she took.

When the female is ready to receive the attentions of the males she does not fight them off, nor do the males fight among themselves. The spawning act occurs at a depth of from two or three inches to one foot in the shallower waters that have been warmed by the sun's rays. Water temperatures were observed on two occasions. On March 24, 1935, the temperature was 48° F. and on March 29, 1936, it was 43° F. Both observations were made at about 4:00 P. M.

My only observations of the spawning act were made on the two dates mentioned in the preceding paragraph. The behavior of the fish was essentially the same on both occasions. Both observations were made on the species *E. lucius* but probably the act of both species is very similar. On both occasions the fish were in about ten inches of water and were swimming slowly around in a circle about two feet in diameter with their bellies rubbing violently against each other. At short intervals during the act the fish flapped violently and it was then that the eggs and milt were ejected. The female was accompanied by two males on the first occasion and by three on the second. The eggs upon being ejected and fertilized drop to the bottom and adhere to the vegetation. Spawning takes place on bright days between 2:00 P. M. and 5:00 P. M., reaching its height at about four o'clock.

Approximately one month after the eggs are laid the young are ready to migrate to the lake. At this time they are from three-fourths of an inch to one and a half inches long.

Many stomach examinations have been made by the writer and the late Professor Thomas L. Hankinson of pike taken during their spawning seasons (1933 to 1936 inclusive). In most individuals, however, the stomachs were empty. Two specimens of *E. lucius* taken March 23, 1935, contained only black bass. One of these pike, an eighteen-inch female, had an eight-inch black bass in its stomach. The other pike, a sixteen-inch male, had taken two three-inch black bass. All the bass were too badly digested to make species determination possible. Another pike of the same species, a male nineteen inches in length, had taken eleven skipjacks, *Labidesthes sicculus,* that varied from two and a half to three inches in length. Other specimens of pike taken during the same and other years contained golden shiners, bluegills, and fish hooks and lines. The food of the young of *E. cermiculatus* was examined by Hankinson and found to consist of insects, largely larvae. A few adult pike of the same species were also examined by Hankinson but the data were not available for this report.

THE FOOD OF SCULPINS (COTTIDAE) IN CENTRAL NEW YORK

Wm. J. Koster

Cornell University, Ithaca, N. Y.

Most of the fish used in this study were collected from Cayuga Lake and trout streams within a radius of twenty miles of Ithaca, New York. Some of those examined were from more distant places and a few were from non-trout waters. *Cottus bairdii bairdii* Girard was taken only in the streams, *Cottus bairdii kumlieni* (Hoy) only in Cayuga Lake, and *Cottus cognatus* Richardson both in the streams and in Cayuga Lake. The collections were made during the non-summer months. The fish were either seined or speared and were preserved at the time of capture. Examination was made of the stomach contents only. The materials in the alimentary canal were not included because of the great changes in the relative volumes of the various items as a result of unequal digestion. The volume of each item was estimated and recorded in per cent.

Materials eaten

Vegetal Matter

What little vegetation is taken by sculpins consists primarily of filamentous algae and *Chara*. Seeds and fresh fragments of vascular plants are occasionally found in their stomachs. Two specimens of *C. b. kumlieni* contained *Chara* in good quantities, these being the only records of plants as a dominant food item. All the rest of the vegetal matter may well have been taken in accidentally along with other forms.

Animal Matter

Annelida. Oligochaetes were found in a few stomachs. One object was doubtfully identified as a leech.

Mollusca. Both small mussels and snails are occasionally taken, these usually being found in crushed condition.

Arachnida. Spiders are very rarely taken.

Crustacea. Small sculpins are commonly found with ostracods and copepods in their stomachs but these rarely form a major food item. *Gammarus, Hyalella, Asellus* and an occasional crayfish are eaten by the larger fish.

Insecta. The great bulk of sculpin food consists of aquatic insects, chiefly in the larval state. Representatives of seven orders have been identified from their stomachs but only three of these, Ephemerida, Trichoptera and Diptera are of much significance.

The identifiable stonefly nymphs seemed, with one exception, to belong to the genus *Perla.* Mayfly nymphs of all types are freely taken, apparently indiscriminately. Members of the Baetinae are taken by sculpins of all sizes while the somewhat larger forms of the Ephemerinae and Heptageninae are more common in the bigger fish. No damselfly and but few dragonfly nymphs were found in the sculpin stomachs. Caddis larvae, particularly those of the genus *Hydropsyche,* are an important food item. Except for the micro-caddis and the small sandcase bearers such as *Helicopsyche,* caddicefly larvae are usually ingested without their cases. The larva of the alder-fly, *Sialis,* was the only member of the Neuroptera represented. Among the Coleoptera, the water-penny, *Psephenus,* and the larvae and adults of the Elmidae are occasionally eaten. Midge (Chironomidae), black-fly *(Simulium)* and other small dipterous larvae are frequently found in sculpins of all sizes. The larger fish sometimes eat crane-fly larvae such as *Antocha, Eriocera* and an occasional *Tipula.* The terrestrial insects are represented by an ant, a true bug and some fragments of undermined forms.

Fishes. Very young sculpins were taken more frequently than all other species combined. Fan-tailed darters, *Catonotus f. flabellaris* (Rafinesque), undetermined cyprinids, and a single young trout constituted the rest of the fish food found.

Fish eggs. Most of the fish eggs taken from sculpin stomachs were sculpin eggs. One specimen contained partly digested eggs that may have been *Catonotus f. flabellaris* (which was nesting along with *Cottus*) but were probably *Cottus.* Two fish contained lake trout eggs.

Trash. Relatively little trash is found in sculpin stomachs, although bark, sand and even good size pieces of gravel are occasionally present. One or two stomachs contained nothing but trash.

Food of Cottus bairdii bairdii Girard (See Table 1.)

Forbes (1883) examined six specimens from southern Illinois which contained 25% fish (one with ctenoid scales), 44% insects and 29% crustacea *(Asellus).* Pearse (1915, 1918) found mostly amphipods (59.1%), mayfly nymphs (24%), midge larvae (7.5%) plus a few miscellaneous items in thirty sculpins averaging 39.6 (20.5-57.5) mm. that were taken in certain Wisconsin lakes from July to October. Twenty-six specimens taken from the spawning beds of trout from December to February contained caddis and other insect larvae (Surber, 1920). Turner (1922) has furnished the bulk of the data available on the food of the young of this form. Midge larvae, mayfly nymphs, and amphipods formed the bulk of the material found in thirty-five stomachs. A few fish eggs (species not designated) are also reported. The specimens were from Put-in Bay, Ohio and ranged from 12 to 22 mm. in length. Greeley (1927) examined the stomach contents of two speci-

mens and found caddis larvae, midge larvae, mayfly nymphs and a small amount of algae and diatoms. Dence (1928) found a few chironomid larvae in sculpins. Nurnberger (1930) reports malacostraca, insects, chironomid larvae and pupae from twenty specimens 20 to 62 mm. standard length from Minnesota. Ricker (1934) examined 56 fish 0.5 to 3.7 inches long taken in Ontario from May to October. He found midge larvae (70%) and small mayfly nymphs (30%) to be the most important foods of the smaller sculpins. The larger individuals ate fewer midge larvae (5%) but ate more mayfly nymphs (64%), particularly of the larger species. Miscellaneous items including crustacea formed but a small part of the diet.

TABLE 1. SUMMARY OF THE FOOD OF COTTUS BAIRDII BAIRDII GIRARD, BASED UPON STOMACH EXAMINATIONS. THE ESTIMATED VOLUME AND FREQUENCY OF OCCURRENCE * ARE GIVEN IN PER CENT

Standard length	20-29 mm.		30-69 mm.		50-69 mm.		over 70 mm		20-77 mm.	
No. examined	45		308		159		3		515	
No. with food	35		257		140		2		434	
	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.
Plant material					trace	0.7				
Algae			0.1	1.2					trace	0.9
Vascular plants										
Animal material										
Annelida										
Mollusca	2.1	2.9			0.2	2.1			0.2	0.9
Arachnida			0.1	0.4	0.1	1.4			0.1	0.7
Crustacea			0.4	2.3	0.1	1.4			0.2	1.8
Insecta										
Plecoptera	2.0	5.7	1.9	3.9	2.6	5.7			2.1	4.6
Ephemerida	27.9	68.6	22.0	36.2	13.0	36.4			19.5	38.7
Odonata			0.6	1.6	1.6	2.1			0.9	1.6
Trichoptera	21.4	51.4	38.9	63.0	55.1	81.4			42.6	67.7
Neuroptera			0.2	0.8					0.1	0.5
Coleoptera			1.1	3.1	0.5	5.0			0.9	3.5
Diptera	39.6	82.8	27.9	58.4	21.4	56.4	99.0	100	27.1	59.9
Terrestrial			0.9	1.6	0.1	0.7			0.5	1.2
Undetermined	7.0	11.4	4.6	8.2	2.4	7.1	1.0	50	4.1	3.5
Fish					2.3	3.6			0.7	1.2
Fish eggs			1.2	1.2					0.7	0.7
Undetermined			0.2	1.6	0.4	1.4			0.2	1.4

* In this and the following tables the calculations are based on the number of specimens containing food.

Representatives of three orders of insects, Ephemerida, Trichoptera and Diptera, formed almost 90% of the diet of the 434 specimens of this subspecies that contained food. Turner (1922) and Ricker (1934) have pointed out that this form does not pass through a stage during which it feeds largely upon entomostraca, but commences upon a highly insectivorous diet as soon as the yolk sac is absorbed. The smallest fish examined during the course of this study (20-29 mm.) subsisted primarily upon small dipterous larvae and mayfly nymphs. The smaller caddis larvae were also taken in good quantities. These latter, which formed about one-fifth of the bulk of the food of the smallest fish, comprised over one-half of that of the larger fish while the Diptera and Ephemerida dropped to about one-half of their former value. Trichopterous larvae formed approximately two-fifths of the diet of all

the fish containing food, dipterous larvae somewhat more than one-fourth and mayfly nymphs almost one-fifth. Miscellaneous items amounted to slightly more than one-tenth of the bulk.

Food of Cottus bairdii kumlieni (Hoy) (See Table 2.)

Four specimens of this subspecies 61-108 mm. long from Wisconsin contained 57.5% *Mysis* and 42.5% *Pontoporeia* (Pearse, 1921). Sibley and Rimsky-Korsakoff (1931) reported aquatic insects and scuds from ten sculpins 3.3 to 4.6 cm. long taken in the St. Lawrence River.

Cottus b. kumlieni shows a more varied diet than either of the other forms. The three insect groups that composed the great bulk of the food in the others comprised less than half in the 82 specimens that

TABLE 2. SUMMARY OF THE FOOD OF COTTUS BAIRDII KUMLIENI (HOY), BASED UPON STOMACH EXAMINATIONS. THE ESTIMATED VOLUME AND FREQUENCY OF OCCURRENCE ARE GIVEN IN PER CENT

Standard length	20-29 mm.		30-49 mm.		50-69 mm.		20-69 mm.	
No. examined	1		59		55		115	
No. with food	1		43		38		82	
	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.
Plant material								
Algae			1.2	4.7	2.6	2.6	1.8	3.7
Vascular plants			0.3	2.3	2.5	2.6	1.3	2.4
Animal material								
Annelida			2.1	2.3	3.6	5.3	2.8	3.7
Mollusca					3.9	5.3	1.8	2.4
Arachnida								
Crustacea	100	100	13.5	32.6	11.9	26.3	13.8	31.7
Insecta								
Plecoptera			4.8	11.6	1.6	5.3	3.2	8.5
Ephemerida			13.4	27.9	28.2	39.5	20.1	32.9
Odonata								
Trichoptera			17.4	32.6	13.4	36.8	15.3	34.1
Neuroptera								
Coleoptera			5.2	7.0	2.6	2.6	3.9	4.9
Diptera			11.3	27.9	10.2	23.7	10.7	25.6
Terrestrial								
Undetermined			25.1	34.9	7.8	10.5	16.8	23.2
Fish			2.3	2.3	4.9	5.3	3.5	3.7
Fish eggs			2.3	2.3	5.8	7.9	3.9	4.9
Undetermined			1.7	4.7	0.7	2.6	1.2	3.7

had food materials in their stomachs. Unlike the preceding subspecies, the larger fish secured a greater proportion of mayfly nymphs than did the smaller ones. This was probably due to a difference in the mayfly faunas, since large mayfly nymphs were relatively scarce in the streams where the *C. b. bairdii* were collected, while the large forms of the Ephemerinae were common in the lake. Crustacea, principally "scuds" comprised about 14% of the food taken. The remainder of the identifiable material consisted of worms, stonefly nymphs, water-pennies, fishes and other miscellaneous items.

Food of Cottus cognatus Richardson (See Table 3.)

Sir John Richardson (1836) found "fragments of *dytisci,* and other fresh-water insects and *crustacea,* and also of some small fish" in one

of the type specimens of this species. Kendall and Goldsborough (1908) found insect larvae, chiefly those of the black-fly, in some sculpins from the Connecticut lakes. Rimsky-Korsakoff (1930) reported 40% mayfly nymphs, 40% midge larvae and 20% caddis larvae from four specimens 5.1 to 6.2 cm. long from northeastern New York. The bulk of the food of ten individuals from northern New York was composed of aquatic insects. Some fish and some higher plants were also found (Sibley and Rimsky-Korsakoff, 1931). Ten *C. cognatus* from Gill Creek (Upper Hudson Drainage, New York) taken August 10, contained 22% Ephemerida, 31% Diptera, 2% Plecoptera, 30% Odonata, 5% miscellaneous, and 10% fragments (Pate, 1933). Pate (1934) also reports that three sculpins from the Raquette Watershed 2.9 to 4.4 cm. long contained 100% insects.

TABLE 3. SUMMARY OF THE FOOD OF COTTUS COGNATUS RICHARDSON, BASED UPON STOMACH EXAMINATIONS. THE ESTIMATED VOLUME AND FREQUENCY OF OCCURENCE ARE GIVEN IN PER CENT

Standard length	20-29 mm.		30-49 mm.		50-69 mm.		70 mm or over		20-95 mm.	
No. examined	113		390		165		62		730	
No. with food	101		357		133		32		623	
	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.
Plant material					5.04	5.3			trace	1.1
Algae	0.9	5.0	0.4	1.7					0.4	1.8
Vascular plants			trace	0.3	2.1	0.8	0.2	3.1	0.5	0.5
Animal material										
Annelida										
Mollusca					0.1	0.8			trace	0.2
Arachnida			0.1	0.3					0.1	0.2
Crustacea	5.8	46.9	1.9	10.3			0.6	3.1	2.2	13.6
Insecta										
Plecoptera	0.2	1.0	1.8	4.5	2.4	6.0	7.2	9.4	2.0	4.5
Ephemerida	33.0	63.4	39.8	51.2	30.8	50.4	9.1	28.0	35.2	51.4
Odonata	0.2	1.0					3.1	3.1	0.2	0.3
Trichoptera	4.2	11.9	17.5	30.3	29.6	50.4	26.2	43.7	18.4	32.3
Neuroptera			trace	0.3	1.3	3.0	3.4	6.2	0.5	1.1
Coleoptera			0.2	0.3	1.1	3.7	4.7	6.2	0.6	1.3
Diptera	52.4	76.2	31.4	68.9	23.5	50.4	19.9	31.2	32.5	64.2
Terrestrial			0.1	0.3	trace	0.8			0.1	0.3
Undetermined	2.3	4.0	5.8	0.7	8.1	9.8	9.7	15.6	5.9	7.4
Fish			0.3	0.3			6.2	9.4	0.6	0.8
Fish eggs			0.3	0.3	0.8	0.8	9.4	9.4	0.6	0.6
Undetermined			0.2	0.8	0.1	0.8	0.3	3.1	0.2	0.8

The smallest *C. cognatus* frequently contain inconsiderable amounts of entomostraca. One (8.4 mm.) captured within a few centimeters of the nest contained about one-half entimostraca and one-half chironomid larvae which showed that insects are taken from the very start in this species also. Immature stages of the Ephemerida, Trichoptera and Diptera formed over 85% of the diet in the 623 sculpins containing food. Over one-half of the food of the 20-29 mm. fish consisted of dipterous larvae, whereas they formed less than one-fifth in the largest (70-95 mm.) fish. Miscellaneous food items and trichopterous larvae increased in relative importance with the decline of the Diptera. Although the importance of the Ephemerida remains relatively constant except for the largest sculpins, the forms eaten are not the same

throughout. The smaller fish feed primarily upon the small baetinids and heptagenids, while the large burrowing nymphs of the Ephemerinae are taken principally by the bigger fish.

The Relation of the Food of Sculpins to Trout

The food of sculpins is most likely to concern man through its influence on the trouts. This may be brought about by predation of the eggs and the young or by competition for the available food. It has been almost customary, with some few exceptions, when writing of the sculpin to mention that it is a notorious trout-spawn eater, and equally customary to omit data supporting such a view. Both predation and competition are most likely to occur in the colder months of the year because it is during this time that the eggs and small trout are most available and the trout are forced to secure a larger portion of their sustenance from the bottom which is also the source of practically all of the sculpin food.

Surber (1920) was one of the first to question the accuracy of the statement that sculpins are very destructive to the eggs and young of trout. He examined twenty-six sculpins taken from the spawning beds of trout from December to February and found that they did not contain either the eggs or the young of that species. Greeley (1932) and Ricker (1934) concluded from their studies that *Cottus* neither congregated on the spawning beds nor ate large quantities of eggs. One sculpin secured by Greeley in Michigan contained a single trout egg.

The relation of sculpins to brook trout spawn was studied several successive years in a stream (Beaver Brook) near Ithaca, N. Y. A tendency of the sculpins to congregate on the trout redds was not noted. Trout eggs were taken from stomachs of trout but never from stomachs of sculpins that were secured at the same time. Eleven specimens of *Cottus cognatus* that were captured on the spawning beds of lake trout in Otsego Lake on April 12, 1935 by Drs. Greeley and Greene were received and their stomachs examined. One sculpin contained an egg and an egg shell of trout, the rest had only insects. The sculpins were spawning and the trout were hatching at this time. One of a series of *Cottus b. kumlieni* taken December 7, 1933 from Cayuga Lake yielded a lake trout egg (?).* The record of Greeley (1932) and the two presented here are the only accessible data showing the destruction of trout eggs by either *Cottus bairdii* or *C. cognatus.*

Greeley (1932) has concluded that the actions of the female trout in guarding and covering the redd are sufficiently effective to prevent any significant losses of trout spawn to sculpins and other predators.

* The identification is somewhat questionable but Professors A. H. Wright and G. C. Embody, who kindly examined it, concluded that it was probably a lake trout egg although somewhat small for that species.

The answer to the question, "Do sculpins eat trout eggs?" is "Yes"; but the answer to "Do sculpins destroy large numbers of eggs that otherwise might have developed into young trout?" is "No",—at least as far as the brook trout is concerned and probably the brown and rainbow trouts also. The relation to lake trout will bear further investigation since the only two records of trout-egg predation found during the course of this study were of lake trout eggs and Greeley (1936) has indicated that lake trout apparently make no attempt to build a redd and thus leave the eggs exposed to the attacks of predators throughout the incubation period.

The only published record available showing destruction of trout by either of the two species concerned is that of Lincoln (1933) who states that he noticed sculpins in Michigan (presumably one of the forms under discussion) taking recently planted fingerlings up to and including two inches in length.

Most of the sculpins examined during the course of this investigation came from trout streams, many from areas well supplied with young trout, such as Beaver Brook. Several of the collections were made at times when sac-fry and small advanced fry were common in the streams. In spite of this apparent opportunity for consuming trout, only one sculpin was found to have done so. A fingerling (approximately 25 mm.) was eaten by a large nesting *C. cognatus*.

The second way sculpins may be detrimental to the welfare of trout is by competing for the available food. Pate (1933) concluded from some studies made in the Upper Hudson Watershed during 1932 that *C. cognatus* and the speckled trout, *Salvelinus f. fontinalis* were not competitors because the materials eaten by the former were relatively unimportant to the latter. From time to time during the year, the stomach contents of brook, brown, and rainbow trout were examined and the contents compared with those of sculpins (principally *C. cognatus* but also *C. b. bairdii*) taken in the same locality. Since trout are known to feed in all planes of the water from the bottom to the surface while sculpins are restricted to the former, it is only when the trout are securing all or part of their food from the substratum that the two forms may, and do to some extent, compete. This rivalry is inclined to be more severe to the smaller trout, which are more dependent on the small bottom fauna. It is, therefore, inclined to be of more significance in nursery streams than in fishing streams. Because the competition afforded by the sculpins is restricted to one plane, it appears to be less than that furnished by fish that compete at all levels, such as the horned dace and common shiner. It seems that the competition furnished by sculpins is probably the most valid objection to their presence in trout waters, but this may be counter-balanced, in certain cases at least, by their value to the larger trout as a forage fish.

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FRESH WATER FISHERY PROBLEMS OF THE BRITISH ISLES

W. RUSHTON

London, England

I wish first of all to thank you for the hospitality that has been extended to me and to express my appreciation of the value of the exchanges of opinion I have heard among the various members of your Society. I have been particularly charmed with many of the younger members who have taken an opportunity to make my acquaintance and to discuss with me some of their own problems.

For many years I have corresponded with Professor Embody of Cornell University. On his invitation I decided to visit him, and he suggested that I attend this meeting of the American Fisheries Society. He said you would like to hear something from me, and in a weak moment I drew up an outline of some of the problems met with in biology in the fisheries in England. I thought first of all I would relate a few experiences in connection with my own investigations, and then draw your attention to some of the problems which you are faced with and which we also meet.

First of all let me say that there is in England no piece of investigation on such an extensive scale as that covered by the eighteenth report of the Conservation Department of the state of New York, "A Biological Survey of the Erie-Niagara System," a copy of which Dr. Embody sent to me and which I refer to from time to time. I am quite charmed with the way in which the various subjects dealt with are worked together from the cooperative point of view.

I have been in the hatchery area of New York state with Professor Embody; I have been on the salmon rivers of Nova Scotia with Dr. Huntsman, and I have also had the opportunity of seeing your great Wolf lake hatchery. In Britain there are no state hatcheries; the only fish hatcheries are those run by private individuals (so far as fresh water fish are concerned) for trout rearing and for stocking such streams as become depleted through over-fishing or have no facilities for spawning. These hatcheries are operated by very able and experienced men; one hatchery I know of is run by an Oxford trained man, an experienced biologist, who has some connection with about half a dozen hatcheries all told. There are no salmon hatcheries in Britain, such as the one in Cape Breton that I visited with Dr. Huntsman; in odd cases in Scotland a man may collect a number of eggs, hatch them out and when the yolk sac is absorbed transplant them, but in general we start with the position that there are no salmon hatcheries.

In Britain the practice is a little different from yours. They not only take the trout to the fingerling stage, which is very admirably done, so

far as I can see, on this side, but they also keep stocks of yearlings, two year olds, three year olds, and sell any of these at a reasonable price when the demand arises. So that if a man has an interest in a piece of river where there are no sporting facilities he can buy three year olds if he wishes, or, if he is not hurried, he can buy two year olds or yearlings or even go back to fry.

Another practice which is followed by many owners of streams is to buy two year olds, keep them in small artificial ponds, feed them up and put them into the rivers the following year. Others buy their yearlings in February, keep them in artificial ponds, feed them on various foods, including salted cockles and salted mussels, put them into the stream in April and fish them out the same year. The result is they can get big fish, over ten to twelve inches.

With regard to the foods of fish, most of my investigations and researches have been carried on in the field, with the result that one gets to know the creeks and streams and what they will carry. Undoubtedly our best streams are to be found either in the chalk or the limestone areas, probably due to the better flora and fauna to be found there. The natural fish foods in our best streams consist largely of *Gammarus* or freshwater shrimp, Ephemeridae, Caddis, a few Mollusca, dipterous insects, etc. There are few mollusca in the fast flowing streams, but these are well stocked with other fauna, and side by side with that you get extremely abundant flora. In a good trout stream the flora will consist largely of *Ranunculus fluitans,* or water buttercup, starwort, *Hippuris* and patches of river grass. They endeavor to avoid mud banks because they encourage the prevalence of *Elodea.*

In a good trout stream the flora is so prolific that it is necessary to weed at least twice a year, and the common practice is to weed in April and again in September. These streams are what you would call ideal trout streams. Then you come to the slower moving streams, which are generally deeper; and these are more adapted to the coarser type of fish. Taking the Thames as an example, you may get brown trout towards the upper areas fed by chalk tributaries, but when you get down to the lower freshwater reaches the Thames is adapted only to coarse fish. On any Saturday or Sunday during the fishing season on the banks of the Thames above Richmond you will find one or two hundred people fishing for coarse fish, and that may be regarded as one of the few types of free fishing.

There are no fish farms in England where coarse fish are reared to any considerable extent—and by coarse fish I mean such species as roach, bream, rudd and pike. If a club wants to stock its waters with such fish it generally gets permission to net out some lake or impounded water and stock its rivers from that source. For instance, many of you are aware that every year there are introduced into the Thames thousands of fish which have been netted from the storage reservoirs of London's water supply, the purpose being to afford an opportunity for

what we refer to as free fishing to people who cannot afford to pay the prices demanded for fishing for trout and salmon.

With regard to the diseases of fish in hatcheries in Britain, most of them are somewhat similar to yours except that we do not seem to have ulcer disease. I believe in this country you have the disease which affects the thyroid gland, sometimes referred to as thyroidea, commonly called goitre. One experience I had in that connection may sometime be of use to you. *Salvelinus fontinalis* is not indigenous to Britain but occasionally it is used in some streams. Four years ago I had sent to me four specimens of *S. fontinalis* of a length of fifteen inches which had been affected by a serious enlargement of the thyroid gland. A pathologist who was consulted assured me that this thyroid condition in the *fontinalis* was pathologically similar to the condition resulting from goitre as it occurs in human beings. Inquiry into the history of these fish indicated that eggs of *fontinalis* had been imported from the continent and reared in a hatchery in Scotland, that when the fish had attained the yearling stage half of them had been sent to an area in Cornwall, near Tavistock, and the other half had been kept in Scottish waters. The thyroid condition did not develop in the fish which remained in the Scottish waters but did develop in the fish which had been put in the Cornish waters. In one case the water is slightly acid and in the other it is neutral, or slightly on the alkaline side. A step further was taken; eggs of brown trout and *fontinalis* were obtained and put in separate aquaria, and a man was instructed to feed them with a common diet. When they were two year olds the *fontinalis* developed a thyroid enlargement, whereas in the brown trout the thyroid was not enlarged at all. These fish were kept in ordinary drinking water such as is supplied to the metropolis. The explanation I cannot give, but it would rather suggest that *fontinalis* is somewhat more susceptible to thyroid than the brown trout.

Another disease found in our waters, which I have discussed with many of you, is that bone of contention, furunculosis. Those of you who are familiar with the diseases of fish know that furunculosis is a difficult and almost impossible thing to deal with. For five consecutive years a colleague and I made a careful study of the conditions on four miles of a stream which is fed from springs, about fifty miles from the source. It is a chalk stream with a gravelly bottom and no signs of pollution. The water was regularly analyzed; bacterial counts were taken from time to time; temperatures of water and air were taken daily. We examined every fish which showed any signs of going over, and in one year on that four miles of stream we took out six hundred trout all of which gave definite indications of furunculosis. The irony of it was that the fish that first went over with the disease were the best fish, three year olds which had not been reared in a hatchery, the stream being self-stocking; about eight years had elapsed since any fish had been introduced into that stream. We were not allowed to clear the stream out, but

we raked over the spawning beds, and our experience is that after the spawning season in February the bulk of the fish which go down are male, and in July, when the temperature is about seventy, the bulk are female. We found there were two peaks of mortality during the year, a low one in February and a high one in July.

The Scottish people working on salmon have had a somewhat similar experience. In 1935, about two or three hundred miles from the mouth of the river Wye, three hundred salmon went down with furunculosis in an area of about a mile, while no other area either above or below was similarly affected, and there was no isolation of the area in which the disease occurred. The explanation I cannot give. I should like very much to be able to solve this problem as it affects the fish in our natural streams; you may be able to deal with it in hatcheries. It has been suggested that a certain diet will cure furunculosis. I am quite open to accept definite proof that any particular kind of food will cure furunculosis, but certainly up to the present time it has not been demonstrated, at least in Europe, and from what I have heard I think the same applies to other countries.

Another problem which faces us in Britain is one which I do not think you have to meet in this country. I have travelled a good many miles on this continent by automobile and by train within the last few weeks. You have large lakes and water areas; your rivers are small as compared with your lakes, and your roads are not as numerous in proportion to area as ours are. It is obvious, therefore, that you have not had to deal with the problem of road dressing. A few years ago in our country there was a strong controversy with regard to this question, and the point at issue was the use of bitumin or tar for roads. Now, bitumin as used on roads means native bitumin or the residue from oil refineries; it is one of the by-products of the oil industry. Tar contains a toxic substance; bitumin does not, and so the controversy arose of bitumin versus tar. So strong did the controversy become that the Ministry of Transport put a ban on the use of tar near a good fishing stream. You can understand what happened: you have a gas industry which makes an excellent material for road surfacing, but washings from it are toxic to fish life; you have another substance from another country, alleged to be non-toxic, and so the controversy proceeded of tar against bitumin. Finally the tar industry thought it was time to put their house in order, so that they financed a field experiment on two portions of road, one treated with tar and the other treated with bitumin. The rainfall was recorded and fish ponds were built in which river water plus washings from a tarred road and washings from a bitumin road could be controlled. It was found that independent of either tar or bitumin there was a time when the dust from the road was sufficiently toxic to make the fish sick, even if they recovered. There was still a certain toxicity in the tar, but of so dilute a nature as not likely to occur in ordinary working conditions. The Ministry of Transport have now relaxed a

little of their censure on tar roads, although the by-law is still carried out faithfully by some of the surveyors near fishing streams.

On the question of pollution, I can say that in the last few weeks I have seen only one area in which I should say that pollution was taking place. Going with Mr. Taylor of McGill University up to his hatchery we passed a paper mill from which was passing an effluent of an alkaline nature, running into the stream. In England there are more towns and they are closer together; in the north it is a manufacturing country. There are distilleries in Scotland and beet sugar factories in various parts of the country. There are sewage works, cider factories, milk factories, producing effluents many of which can be rendered innocuous only by expensive treatment. So far as the sewage problem is concerned, all of you have had to deal with it and know exactly what the difficulties are. You are familiar also with the effluent of milk factories, a heavy liquid of a proteinous nature giving rise to fungal growth down the river. You get a similar thing from a sugar beet factory, with this added factor: in the preparation of sugar from sugar beet there comes a time when they take off the water by means of vacuum evaporators and they need a tremendous amount of water for washing and for cooling. Therefore they take from the stream anything up to 30,000 gallons per hour over the whole twenty-four hours of the day; that water is not only infected but also raised in temperature. The argument of the beet sugar manufacturers is that they make the sugar between the early part of December and about the end of January or beginning of February, and that during the summer months the river can recover. But the conditions brought about by the operation of these factories along the sides of streams are such that you get in the stream a heavy fungal growth and a heavy mortality among the fish. It so happens that the sugar beet factories are subsidized in order that they may be able to carry on—they could not do it alone; so that it is the duty of the Ministry of Agriculture and Fisheries both to encourage beet growing for the benefit of the farmers and to discourage pollution for the benefit of the fishermen. Ways and means of dealing with this effluent have been devised and are now in operation.

At the present time I have a problem to deal with in connection with the effluent from a well known cider factory. This factory is situated on the banks of a tributary of the river Exe, which comes out near Exeter on the south coast. The method of making cider is very simple. Apples are collected by the thousands of tons; they are graded, the juice extracted and stored, and what is left is sent to factories where they make jellies; the pectin is extracted and used in the manufacture of fruit jellies, and so on. During a certain part of the year the liquid which has been stored is bottled. In that bottling process the cider has to be filtered and then passed through filter presses made up of a filter pulp which consists largely of cellulose with a certain amount of asbestos. The filter pulp will perhaps stand two or three feet high with thicknesses of

filter papers separated by tin. The cider is forced through these filter presses so that when it comes out it is practically as clear as water. That filter pulp has to be washed before it is re-used, and coming from it you get quite heavy deposits of a carbohydrate of pectic or dextrine nature. The liquid is also eventually acid. You can get rid of the acid and of the suspended material and produce an effluent which is as clear as drinking water, but if you put it in a stream a heavy deposit of the well known fungus *Sphaerotilis natans* appears. In an analysis of this material your chlorides will be practically nil, perhaps one part per hundred thousand, but when you come to your oxygen absorbing permanganate it is in the hundreds, certainly in two figures on the non-decimal side. Your B. O. D., biological oxygen demand, in five days would be certainly in the eighties, and so on. If you break down the pectin with hydrochloric acid you will find it is in the neighborhood of about .01 to .08 per cent of cane sugar. Pectin, as those of you who are familiar with chemistry are aware, is a non-fermentable carbohydrate; it is only when it is broken down to a lower carbohydrate that fermentation can take place. What happens in the stream is that the higher carbohydrate is broken down from the action of the oxygen in the water in solution and brought down to the lower sugars, and then it acts as a medium for fungus to grow on. If the question be asked: is it a pollution, one has a rather queer difficulty to get over. Fish have been seen living over the top of that fungus, therefore I cannot say it is pollution in that sense; but certainly it has a detrimental effect on the food of all fishes; it prevents the normal growth of fauna and flora, and when the fungus dies down it gives origin to a black deposit.

Perhaps I might refer also to what might be called a natural pollution. Peat areas in your country are not common. In Scotland there is a trout hatchery which gets its water from an upland peat area. The main stream runs along a valley, augmenting its waters from the peat lands. At certain times of the year, after a period of drought, the acidity of that water goes up slightly, and unless care is taken it will coagulate the mucous along the sides of the fry and fingerling. Alongside this hatchery there is a hill which before the war was covered with trees, but during the war the trees were taken off for trench purposes. At the bottom of the hill, before you get to the stream, there are Sphagnum beds. The water when passed through the Sphagnum beds is perfectly clear. If two glasses of water were taken, one from the Sphagnum bed area and the other from the peat area, one would be colorless and the other brown, and if one were asked which he would prefer as drinking water he would choose the water from the Sphagnum bed area because of its color. But if you take fish from the river and put them into the Sphagnum water they go over within twenty-four hours, so that there you have what you might call a natural pollution, prevailing to such an extent that it is damaging the fishing in those waters.

There are many other matters with which one might deal if time permitted. I shall conclude, however, with the words of your own Commissioner of Fisheries, Mr. Bell: "So long as the fisheries exist, new problems will be presented that can be solved only by patient and often obscure labors in the vineyard of science."

Discussion

Dr. H. S. Davis (Washington, D. C.): We are particularly fortunate in having Dr. Rushton with us at this time in that we have been enabled to learn at first hand something with regard to the conditions in England and the most excellent work that Dr. Rushton has been doing. I have often felt that American fish culturists are at some disadvantage in having so little opportunity to learn of what is being done in their field in other countries.

I can fully corroborate all that Dr. Rushton has said with regard to furunculosis and the difficult and complex problems to which it gives rise. In this country we have a very peculiar situation in that although furunculosis has been known for years in many of our hatcheries in the east, and there has been every opportunity for it to become established in our streams, there is not the slightest evidence as far as I know that the disease has become endemic in any of our streams in the east. In the west, however, it has become established in many streams and is now presenting a serious problem. So we have the very peculiar situation that whereas in our eastern streams the disease for some reason does not seem to be able to get a foothold, in our western streams the condition is much the same as it is in England and elsewhere in Europe. I do not know why; perhaps this is a wild guess, but there is some slight evidence pointing to the fact that furunculosis did not originate in Europe at all but may have been carried there from this country. This of course is a rather revolutionary idea, but there is some ground for the belief that it might possibly have happened.

Mr. Milton P. Adams (Michigan): I am sure I speak for everybody here when I express pleasure at Dr. Rushton's presence with us at this meeting. I am particularly interested in his references to the beet sugar waste problem of England. Michigan has sixteen of these plants, nine of which are located in the so-called Saginaw Valley, and this type of waste is not only toxic to fish but has the effect of tainting the flesh of the fish which swim in these waters as well as tainting the public water supply.

Our season comes somewhat earlier than the season in England; it starts late in September and is generally over by the first of January. At this time the streams are low, the water is warm, the oxygen demand of the wastes is high, and that combination is generally damaging very soon after the start of the season. These plants were started here some twenty-five years ago. Representatives of the Departments of Health and Conservation went to England and to Germany to see what was to be done with this new and very toxic type of waste. They found that the wastes were all collected together and settled in huge ponds which allowed anywhere from a week to two or three weeks' detention. There has been a great deal of local history in Michigan in connection with the attempt to control this problem. My files are full of copies of court injunctions which have been issued against the industry to restrain the pollution. So far as improvements are concerned there has been little change up to the present time, but I will say that the production of stock feed from the pulp is one of the improvements; formerly all the pulp in the waste was loss. Now the industry has been called together; an association has been formed, and their technical committee is cooperating with our Commission and the Engineering Bureau of the State College is working out a solution. This was started in 1934 by our laboratory experiments. In 1935 a pilot plant, so called, was set up at Bay City, operating about 50,000 gallons a day of

mixed wastes. We have found as a result of that work that the wastes must be segregated. The Steffens process in sugar manufacture is productive of an extremely toxic type of waste, very high in B. O. D., running up to thirty thousand parts per million with high caustic alkalinity. We have decided there is no place in the water for this type of waste, treatment or no treatment. There is a possibility, and a good one, that it can be evaporated to dryness, and I understand our Japanese friends on the other side are willing to use certain of this as seasoning on their rice, and so forth. It is high in phosphate and other material.

The industry has been given to understand that 1939 must see the end of this problem, and they are being given two or three years to accumulate the necessary $75,000 to $150,000 per plant that will be necessary to deal with it. Being developed as it is with the industry and the state cooperating, I believe by that time we shall have an answer in the case of future offenders.

DR. RUSHTON: On the banks of the Ouse, a stream which goes through the city of Ely, there is a large sugar beet factory in connection with which there have been three court cases. In the first case there was no plant there; the next thing that happened was that they pumped the whole lot over on to an extensive area of land and then drained it off slowly during the summer. The next thing they did was to introduce a plant in which they re-used as much of the first washing of water as possible. In 1930 there was a court action. They put their house in order in 1931. In 1931-32 there was no mortality of fish. In 1932-33 there was mortality; something went wrong with the whole thing. So that they won their court action against the beet sugar factory, and they do know how to treat that effluent properly without any results detrimental to the fish.

Some years ago at a place called Carlow in Ireland an injunction was sought by the owner of a flour mill operated with turbines from the river flow. The mill was situated about a mile below a beet sugar factory, and so prolific was the fungus from this effluent that it covered the fins of his turbines and prevented their operation. Since things were not going so very well anyway, the owner thought this would be a golden opportunity to seek an injunction and recover the cost of his plant. This effluent was passed over about fourteen acres of land, but even after that it was still polluted.

MR. LINCOLN: I should like to mention an experience I had with furunculosis. There was a round pond at the hatchery with an intake of about 75 gallons of water per minute. The fish became infected with furunculosis. I happened to have on hand about five hundred pounds of Hewitt's trout food—I do not know whether the Mr. Hewitt, who is here, is the father of this trout food or not, but if he is, well and good. I started feeding this trout food according to the directions that were in the sack that the food came in. After about ten days the losses began to diminish; at the end of thirty days they entirely stopped and the fish carried through the remainder of the summer without any loss whatever. So a bouquet for you, Mr. Hewitt.

MR. HEWITT: I have had six cases of that kind.

EDITOR'S NOTE: Upon Doctor Rushton's return to England, he wrote a member of the Michigan's committee on arrangements, under date of November 9, 1936, his reactions to his visit to Canada and the United States, which are quoted below for the information of the members of the Society:

FISH HATCHERY WORK IN NORTH AMERICA

"During a tour of about six weeks to Canada and U. S. A., a visit was paid to about eight state hatcheries in the state of New York and to what I found to be the largest state hatchery or other fresh water fish hatchery

I had ever seen—the Wolf Lake Hatchery in the state of Michigan.

"State hatcheries as such are entirely foreign to us in England, so that it was with a perfectly open mind that one visited them in America. All of them seemed to be run on somewhat similar lines. A staff of technical workers, supervised by a district supervisor, with reference to a body of scientists for guidance.

"If one compares an organization like that of any state hatchery with one run and owned by a small company or private individual, one is at once struck by the difference in economical working, and it would be interesting to know the cost of production per fish in each set of establishments. One point in regard to the size of the fingerlings produced by what one would call the intensive culture method, where fingerlings up to six inches are produced in a very short time and put into streams or lakes where the feeding must be different and possibly less abundant, what percentage of fish survive; and whereas a four inch fingerling was aimed at in the past, a six inch is now obtainable, but whether a more adaptable fish, one can't say.

"One feature was outstanding in all the hatcheries visited, and that was the most successful were those with a good supply of spring water; those drawing waters from other sources appeared to have all sorts of troubles with disease, etc.

"The work on nutrition being carried out at some of the hatcheries and the selective breeding and rearing was exceedingly fine and pleased me beyond measure, but the amount of work being carried out on disease and the conditions causing it was not developed to the extent one expected, especially as the men are available, some of whom I met at Grand Rapids.

Method of Stocking

"The method of rearing and stocking in practice in America is one not carried out to any extent in any other country I know, possibly due to the conditions both physical and political in America being different to other countries. Stocking with fingerlings is not done much in Britain unless the areas stocked are the upper parts of a river where suitable food for young fish is available. One wonders what percentage survive the winter and whether any record is kept or obtained of the fish caught against the fish put in, or what determines which river shall be stocked and when and where.

American Fisheries Society

"This meeting impressed me very much, and the organization of the local branch was very well done. I, as a stranger from across the seas, found myself among friends within an hour of arriving. The range of the papers, the enthusiasm of the younger members and their general desire to compare notes with me was encouraging to one's work on this side. One gained a considerable knowledge of local activities from the men from the University of Michigan who put papers before the Society. To hear from time to time discussion on things such as one knows in Britain makes one realize how small the world is and how alike are the men of America to those of Britain. Such meetings must be all to the good.

"Personally, I was pleased with the way I was received by everybody attending the meeting. I was a little surprised at the publicity given and shall prize for a long time the memory of my visit to Grand Rapids. It would be folly of me to offer any criticism of your work as I was only in the country a short time, but I would say that in my own mind I am a little puzzled as to whether the method of rearing and stocking fresh waters adopted in America is the best for the country, but I cannot suggest an alternative as your organization is as near perfect as one can see and is far ahead of any organization of its kind in this country."

FISH INCREASE RESPONDS TO GOVERNMENT AND STATE COOPERATION

SWEPSON EARLE

Liaison Officer, U. S. Bureau of Fisheries, Washington, D. C.

During the past fourteen months, while acting as Contact Officer of the Bureau of Fisheries, it has been my duty and pleasure to confer with practically all of the game and fish commissioners in the United States. Federal fish hatcheries and sub-stations (some seventy odd), have been inspected and many more state hatcheries visited in company with state officials. It is Commissioner Bell's aim to promote fuller cooperation in the fishery activities of the Federal government and the states, and to coordinate the work of the Bureau with that of the states.

On my recent western trip, as in other sections of the country, I found the finest sort of cooperation between Bureau and state officials. One fish commissioner told me that to his knowledge the Bureau and his department were hardly on speaking terms fifteen years ago. Today, state and federal-raised fish are fed from the same refrigeration plant. In this, as in other states, the Bureau, to save duplication of effort and waste of fish, submits its applications for stocking public waters to the state commission for checking before any distribution is made. This commissioner stated that he feels since state and government are working in a common cause, i. e., stocking the public waters with fish for the pleasure and recreation, as well as the livelihood, of the fishing public, the work can best be accomplished through cooperation. To foster that attitude in all the states is the Bureau's aim and hope.

Probably the most serious concern of fish culturists today is to find a way to reduce the cost of fish food. In my work I have secured a great variety of information on this subject from all parts of the country. This information I pass on to the Washington office, where it is sifted, frequently tested out at Federal stations, and worthwhile information is passed on; the Bureau acting as a clearing house for the benefit of all the states. When we consider that hundreds of thousands of dollars are being spent annually by the Bureau and the states on fish food, a saving of ten, fifteen or twenty-five percent on this item by the discovery of a new type of food or feeding method is just so much additional money made available for raising more fish or rearing fish to a larger size before planting in the public waters.

In my opinion the most important information for a state fishery commission to possess is that obtained from an inventory or survey of the public waters. A number of states have been fortunate enough to secure the necessary funds for such a survey, and the information thereby developed has more than justified the expenditure in prevention of fish

waste in streams and lakes where the food supply is insufficient, or where pollution or other conditions exist which render waters unfit for fish life.

A fish culturist told me this year that his state had been unable to make a stream survey because of lack of funds, and, as a consequence, it was his opinion that at least a third of the fish planted were lost, due to stocking improper waters. Neither state nor government can afford to waste fish. Publication of figures in the annual report to show so many millions of fish placed in the public waters is not enough. The fishing public wants to catch fish, and no one will deny that this public is greatly on the increase.

While in Yellowstone Park in July, I was told by the Superintendent that up to July 27th, 225,000 persons had visited the Park since the beginning of the season, and they had a record of 84,000 black-spotted trout taken from Yellowstone Lake and other Park waters. This report, even for that period, would not account for more than one-half of the fish actually caught. By the close of the season close to half a million tourists will visit this great national recreation area, and fishing seems to be their favorite sport. What is true of Yellowstone Park will apply more or less to other western areas. I was informed in Montana, Wyoming, Colorado, as well as the Pacific Coast states, that they all had an unprecedented number of tourists this summer, many of whom were undoubtedly lured to the west for the fishing as much as for the scenery.

The problem of holding fish until they attain sufficient size for stocking has been one of the serious ones for state and federal hatcheries in many of our western states. Water and other conditions often force the planting of fish at a size not altogether desirable from the standpoint of best results. This makes it all the more important to know that such fish go into streams well supplied with natural food. Such streams show results, no matter how small the fish placed therein. Convincing evidence of this was shown me in Colorado at the state fish hatchery near La Jara, close to the New Mexico border. There I found a narrow stream, or ditch, in reality part of an irrigation system, which was several miles long. During its entire length it teemed with natural food, insect life and small marine forms, and was supporting several hundreds of thousands of small rainbow trout. The hatchery superintendent told me that these fish were rapidly increasing in size, and on the occasion of my visit, in August, I saw hundreds of fish ranging in size from 5 to 10 inches. Had it not been for predatory birds, the results from this ditch would have been close to 100%. Due to such depredations, it was the superintendent's estimate that there was a loss of about 40% of the fish planted last year. This loss had been reduced this year to perhaps 20%, by adoptation of practical methods of control.

Another illustration is East Lake, in Oregon. The reputation of this body of water had reached me before my arrival in Portland, and while

there I secured the following information from the Oregon Fish and Game Commission: East Lake covers approximately 2 square miles and has an elevation of 6,300 feet. By reason of the temperature of its water, it is ideally suited for eastern brook trout. The trout thrive to an unusual degree because of the abundance of natural food—*Gammarus*, also leeches and small insects. Superintendent of Fisheries Ryckman told me that from April 5 to September 20, (the open season for fishing in the lake) the catch would average a ton a day—336,000 pounds for the season. During the last spawning season, 15,000,000 trout eggs were taken in the lake, and more could have been obtained but for the lack of hatching facilities.

These two illustrations are convincing of the fact that where an adequate food supply exists, although the body of water may be small, satisfying results can be expected. Without such a condition we are wasting money, fish and effort.

In my swing over the United States I have naturally seen a great many fish hatcheries—many pleasing in appearance and maintained in a high state of efficiency—others not so impressive. While the appearance of a hatchery would seem to be secondary in importance to its capacity to produce fish, nevertheless, it is appearance which gives the visitor a good or bad impression, and each year the number of visitors increases. To my knowledge, several of our east coast stations and the Yellowstone Park hatchery will show a registration of from 30,000 to 50,000 visitors during the summer months. In view of this evidence of public interest, which, it is true, is often idle curiosity, it is believed that hatcheries might well assume an educational character—might become places where fishery information could be disseminated. I have heard visitors ask for printed information on the hatchery work—something which they might take home to show the folks what they had seen in some other region of the country. It seems to me we are missing a fine opportunity to gain public support for our fishery activities. What better advertisement for this work of the states and federal government than to make our hatcheries pleasing enough in appearance to attract the public and instructive enough to give them something to think about after they leave?

PROTECTION OF NATIVE FISHES IN THE NATIONAL PARKS

DAVID H. MADSEN

Supervisor of Fish Resources, U. S. National Park Service, Washington, D. C.

The comparatively few Americans who are sincerely interested in the preservation of our native fauna must look with displeasure, if not with disgust, upon the performance of organizations and citizens, both official and civic, who have made such a sorry mess of fish planting in the waters of the United States.

It would take much time and would be repeating facts already well known to refer to the hundreds, if not thousands, of instances where exotic species have been introduced to the detriment and often the destruction of native species in waters of every State in the Union. Not alone have native species of fish suffered from these mistakes, but certain forms of bird life as well have been driven out of large areas, and valuable aquatic vegetation has been utterly destroyed. So general has been the thoughtless, unscientific planting, I should say "dumping" of fish in nearly all waters that not even the waters of the National Parks have escaped. In every Park containing important fishing waters, there have been introductions of exotic fish. Fortunately there still remain a few important lakes and streams which, so far as is known, are still virgin, and every safeguard of which the National Park Service is capable has been thrown around these waters to insure their protection.

The insistent demand from organized sportsmen for trout fishing which appeared so rapidly with the general use of the automobile, resulted in the unstudied efforts of Game Commissions to secure and plant more and more trout without regard to species in every accessible lake and stream. We are not even satisfied to limit these plantings to our American species, but we have brought in the brown trout from Europe, which now is the only fish to be taken in many waters where some native form once thrived.

Perhaps the most tragic result of the intermixing of species is now rapidly taking place in almost all of the important mountain lakes and streams on the National Forests of the West, and even extending into the National Parks.

I refer to the planting of rainbow trout, largely *Salmo irideus,* in waters containing the native, black-spotted or cutthroat trout *(Salmo clarkii).* Black-spotted and rainbow trout cross readily in most waters occupied jointly by the two species. The result is a hybrid, less productive than either, in which the rainbow type predominates and the native characteristics soon disappear. This transformation is taking place over large areas in most of the better trout waters of the Rocky Mountains.

It may be difficult now for the fishermen to determine the composition of his catch, so many are the types due to cross-breeding. Some outstanding examples of the deterioration of native trout through the introduction of rainbow are the following:

Fish Lake, Utah, a mountain lake at 8,700 feet elevation, extending seven miles in length and one mile in width, with much water from sixty to one hundred feet deep, originally contained an abundant supply of native trout. Rainbow were introduced about 1910. In due time a great number of crosses appeared. These fish were fine specimens, attaining a size of twelve pounds or more, producing a fair amount of eggs with very low fertility. Constant stocking with rainbow has continued until the present time with the result that the native trout have all but disappeared. At least 100 rainbow are taken for every native. There are fewer crosses that can be readily identified and a nearly pure rainbow type has been established. Georgetown Lake, in Montana, which a few years ago was second only to Yellowstone Lake as the largest producer of clean black-spotted eggs in the country, is now seriously threatened by the introduction of a comparatively small number of rainbow. The Montana Game Commission is removing all rainbow and crosses that can be taken from the lake in an effort to save the native fish. Grebe Lake in Yellowstone National Park contains fish that fight like rainbow and look like rainbow when first taken from the water but after changing color in the air prove to be crosses showing strong rainbow characteristics. Provo River in Utah, the North Fork of the Snake in Idaho and many other examples might be given. Outstanding is the Madison River where very few native trout remain. Hundreds of other lakes and streams have been stocked with rainbow and similar results may be expected.

So far as is known, Yellowstone Lake and the Yellowstone River above the Falls have thus far escaped the introduction of exotic trout, and from these waters more clean black-spotted eggs are now taken than from all other waters in the United States combined. There are also a number of important lakes on the west side of Glacier National Park that seem still to be free from rainbow. Then there are an unknown number of lakes of varying importance throughout the National Forests, where there is still a chance to preserve the native species. It would seem that the future of the native trout of the Rocky Mountains depends upon the vigilance of the National Park Service and the Forest Service.

Other undesirable exotics have either been introduced directly, or have found their way up the streams from where they were planted, and are now invading National Park waters. Notably the little red fish, or land-locked sockeye salmon *(Oncorhynchus nerka Kennerlyi)*. This fish, introduced in Flathead Lake forty miles below the park, was observed in Lake McDonald for the first time last year, when several specimens were taken. There is danger that this most undesirable species

may continue up stream and invade other important lakes within the Park.

Last year for the first time "dwarf whitefish," were observed in Glacier Park, and a "long nosed sucker," has made its appearance in Yellowstone Lake in increased numbers during the past three years. These fish have not been definitely classified but are believed to be exotic. Efforts are being made this year to trap and destroy the suckers from Yellowstone Lake during their run up stream to spawn.

Much more attention should be given to the effect of the intermixing of the several types of rainbow trout by which the identity of the original types will be lost. There is great need for a more scientific program of fish distribution, looking to the protection of native species and their environment. A careful study would probably show that in many instances such a program would also result in better fishing.

As a means of giving added protection to native species within the National Parks, a very definite fish planting policy has been adopted from which the following is quoted:

> No introductions of exotic species of fish shall be made in national park or monument waters now containing only native species.
>
> In waters where native and exotic species now exist, the native species shall be definitely encouraged.
>
> It is the definite purpose of this policy to prohibit the wider distribution of exotic species of fish within the national parks and monuments, and to encourage a thorough study of the various park waters to the end that a more definite policy of fish planting may be reached.
>
> The number of any species of native non-game fish should not be reduced even where such reduction may be in the interest of better fishing.
>
> There should be no effort to introduce exotic fish or other exotic aquatic life for the purpose of increasing the supply of fish food.
>
> In cases where a lake or stream is of greater value without the presence of fishermen, there should be no stocking of such waters.
>
> In national parks and monuments where there still remain certain lakes which do not contain fish, permission of the Director must be secured before stocking.

Discussion

Dr. Hubbs: So many people have doubted the extensive hybridization of cutthroat and rainbow trout in the western streams that I would like to say I personally have examined a considerable number of streams in the west and found the condition to be exactly as Mr. Madsen says. Unquestionably these two species do hybridize. In an endeavor to collect native trout in isolated desert trout streams in the west, to save samples before they are completely gone, in 1934 I was forced to go up so high in the mountains that I almost knocked the bottom out of my car in an effort to get high enough to secure the pure native stock. The rainbows were almost pure down in the lower stretches, with various grades of hybridization in between. Unfortunately these two do hybridize, and that is all to the bad, because hybrids are almost surely less fertile than the pure species.

THE FISHERIES PROGRAM IN THE TENNESSEE VALLEY

ALVIN R. CAHN

Chief, Biological Readjustment Unit, Forestry Division, Knoxville, Tennessee

The navigation and flood control program of the Tennessee Valley Authority calls for the construction of a series of dams throughout the length of the Tennessee River and on many of its more important tributary streams. With the completion of these dams a series of reservoirs will come into existence, which will vary in size and in physical character according to the physical features of the landscape that will determine the height of the dams and hence the character of the lakes. Each newly impounded area presents a group of problems which, although they may be of similar fundamental character, involve a multitude of details which differ greatly according to the character of the region involved.

It is a familiar fact, which has been emphasized by Mr. Jay N. Darling, Dr. M. M. Ellis, and others, that impounded lakes become, after the first few years of their existence, decidedly lacking in fish productivity. Mr. Darling has referred to the results of dam construction as "biological deserts," and the term is equally applicable to terrestrial and aquatic areas. There are innumerable examples of aquatic deserts, and to list them would be to name practically every large dam so far constructed. In an effort to counteract the known effects of dam construction on the biological resources of the areas involved, the Tennessee Valley Authority created the Biological Readjustment Unit within the Forestry Division of its organization, and charged it with the specific functions which its name indicates: the readjusting of the biological factors of the territory to the newly created physical conditions. The duties of this unit involve both game and fisheries problems, but it is with the fisheries phase of its program that I would deal very briefly at this time.

In days past, the Tennessee River has afforded an abundant supply of fish to serve as food for the people of the valley. A survey of the Tennessee River in the immediate vicinity of Decatur, Alabama, for example, showed that on that portion of the river which will eventually become a part of Wheeler Lake there are at the present time approximately 7,550 fishermen dependent annually upon the river for either their food or their livelihood. These people are now taking out around 300,000 pounds of food fish per year, having a market value of about $37,500. These are river fish, adapted to the river type of environment. With the impounding of the water, Wheeler Lake will come into existence, having physical characteristics wholly different from those of the

original Tennessee River. If the history of other impounded waters repeats itself—and there seems to be no reason why it should not—the "biological desert" looms in the offing. With the large population of the area dependent upon the water for food, the Tennessee Valley Authority recognizes its moral responsibility to make every effort to keep up and to build up the fisheries industry in order that this specter of an aquatic desert may not become a reality. The story of the Wheeler Reservoir is repeated over and over again in connection with every dam which has been constructed and will be repeated with every dam proposed for future construction, and the problem of readjusting the biological aspects of the flooded areas to the new physical conditions is repeated again and again with each new reservoir. I have the opportunity here to outline the program associated with but two of the many areas involved, and have selected the area of the Norris Reservoir and that of the "lower lakes" centering in northern Alabama, as examples.

Norris Dam, 265 feet high, has behind it a large deep lake 72 miles long, with a shoreline of about 800 miles. This reservoir is intended primarily for navigation and flood control purposes, and the plans of utilization call for a fluctuation of water level of from fifty to sixty feet during the year. This fluctuation will create a series of exceedingly complicated problems insofar as the fisheries of the lake are concerned, for it is extremely doubtful whether aquatic vegetation will have an opportunity to become established along the shallow waters of the shore and whether the fish will have an opportunity to propagate under natural conditions sufficiently to keep up the population. Acknowledging the fact that these difficulties exist, and anticipating the problems ahead, the Biological Readjustment Unit in cooperation with the U. S. Bureau of Fisheries, has constructed a hatchery below Norris Dam, where fish (particularly the largemouth bass) will be propagated for the sole purpose of stocking the Norris Reservoir. This hatchery is at the present time practically completed, and the Bureau has placed one of its fish experts in charge. Following the hatching of the fish, the fry will be collected and transferred to a series of rearing pools located around Norris Lake. These rearing pools have been constructed by throwing dams across some of the small, incoming streams. Behind these dams constant level ponds have been established. Two such rearing ponds are now completed, and a third is rapidly nearing completion. More will be constructed as the opportunity presents itself. In these rearing ponds the fry will be retained until they reach a size sufficient to insure their safety upon transplantation into the lake.

Below Norris Dam, where the cold water, coming from the bottom of the impounded water behind the dam, spills forth into the willow-shored, gravel-bottomed Clinch River, an interesting opportunity seems to exist for the development of a trout stream of unusual promise, and it is proposed to undertake this development at once.

Besides the Bureau of Fisheries expert in charge of the hatchery, a fish expert in the employ of the Unit will be placed in charge of the fisheries problems of the entire reservoir. This man will report for duty as soon as he can be employed. He will be furnished a forty-foot laboratory boat fully equipped for investigation of all phases of the fisheries problems, and in the years to come a complete study will be compiled to show the development of this great lake in all of its aquatic phases, including the chemical as well as the biological aspects. It is of interest to note in passing that the Bureau of Fisheries has in its files a mass of data on the original Tennessee River previous to the impounding of the water, so that the story will be remarkably complete.

Wheeler Lake and its immediate neighbors—Pickwick, Wilson and Guntersville lakes—form a group of lakes connected by locks. The dams which create these lakes are relatively low, yet in spite of the fact that the Wheeler Dam is but seventy-two feet high, Wheeler Lake is 110 miles long and has a shoreline of 951 miles. In contrast to Norris Lake, these "lower lakes" are shallow. In this area which, parenthetically, we believe will be one of the great migratory waterfowl areas of the United States once it is developed for this use, the fisheries problems are essentially those of shallow-water lakes. A fish hatchery is proposed to be established in cooperation with the Bureau of Fisheries on the Elk River, where approximately 150 acres will be developed to stock this particular chain of lakes. The fisheries problems here will again be in charge of an expert fish man, who will report in February, following the impounding of the water behind Wheeler Dam. He also will be furnished a floating laboratory, and here again a series of comparable studies will be made involving all of the fisheries aspects of shallow lakes. These studies undertaken on the Norris and lower lakes reservoirs will yield a mass of information which should prove of immense value, not only from a scientific point of view, but also as a guide which can be followed throughout the entire country wherever dams create large inland lakes. It would seem that never in the history of the country has there been an opportunity comparable to this for a study of the biological and chemical problems associated with large artificial lakes, and the Tennessee Valley Authority and the Bureau of Fisheries intend to make maximum use of the opportunity.

Mention has been made only of the Norris and Wheeler areas, yet there are besides these two dams, five others now under construction and three more proposed in the main river alone. In all, about 600 miles of the Tennessee River will, within the next few years, be changed from a great river to a series of greater impounded lakes. Many of the tributary rivers, such as the Little Tennessee and the Hiwassee, as well as the Clinch, will have dams constructed on them at various places, creating lake-systems tributary to this main chain. The following table gives a few of the more pertinent facts about the various reservoirs:

Dam	Height (feet)	Approximate Area (acres)	Approximate Shoreline (miles)	Length (miles)
Pickwick	107	42,000	550	53
Wilson	137	14,000	360	13
Guntersville	80	55,000	585	80
Wheeler	72	69,000	951	110
Chickamauga	104	34,000	712	59
Fowlers Bend	300	6,300	150	22
Norris	265	35,000	705	72
Gilbertsville	55	160,000	1,200	184

These eight dams alone will form a series of lakes 593 miles in length, with a shoreline of around 5,212 miles. These figures are presented merely to give one an idea of the magnitude of the projects.

As each reservoir is formed, the Biological Readjustment Unit proposes to undertake a series of studies similar to those outlined for Norris and Wheeler Lakes, so that when the entire picture is finished we may be able to present a series of biological studies upon which scientists and conservationists, as well as engineers, may draw for information. Besides these problems of fisheries development, there is the vexing problem of protection. The activities of the Tennessee Valley Authority lie in seven states. It is planned to enter into a cooperative agreement with each State whereby the various States may themselves participate and cooperate in the biological readjustment problems within their boundaries.

The primary function of all this work is the building up of the fisheries industry of the Tennessee Valley in order that an adequate supply of food for the people of the Valley may be maintained, coupled with sport, recreation and health for this population. In pursuing this course, the Tennessee Valley Authority hopes that posterity may never have occasion to level against it the charge that in the creation of its great navigation and flood control program it has neglected or destroyed the valuable fisheries of the area.

Discussion

Dr. Cahn: This paper was written last week. The plans for the development of the Gilbertsville dam have been approved, and that will give us another problem. This dam, which will be seventy-five feet high, will create another lake 184 miles long, with an average width of between three and five miles.

I have here a map of the Tennessee valley in case any of you are interested. You can see what the Norris dam looks like, and you will note the torturous course of that 72-mile lake. The red areas are game refuges for quail, ruffed grouse, wild turkey and deer. It gives you some idea of the size of this thing.

THE PRESIDENT: Each State that is affected by the Tennessee Valley authority is cooperating closely with the Bureau of Fisheries and with Mr. Cahn in working out these problems.

MR. WICKLIFF: Are the trees and shrubbery being cut in the carrying out of this work?

DR. CAHN: I venture to say there has never been a better job of clearance than was made in connection with every one of these impounded lakes. Every tree, every brush was cut, and everything was moved away. The only thing that is being flooded is grass and herbs that have come up since the cutting was made—a marvellous job of clearing. About 280,000 acres of clearance will be necessary for the Gilbertsville project.

THE PRESIDENT: Are there any other questions?

THE SECRETARY: Everybody seems to be staggered.

THE PRESIDENT: We had the same problem on the Columbia River in the state of Washington, with the same cooperation that is taking place here. One hears a good deal about these things over the radio, and it is sometimes worth while to find out what is actually being done.

THE IMPORTANCE OF SPORT FISHING IN MARYLAND

R. V. Truitt and V. D. Vladykov

Chesapeake Biological Laboratory, Solomons Islands, Md.

Although there are no natural lakes in Maryland of importance, sport fishing is very popular. This may be attributed in part to the long coast line bordering on Chesapeake Bay as well as to nine large rivers that flow into it. According to Wells, Bailey and Henderson (1929, p. 109) Chesapeake Bay, together with its drainage areas, amounts to 67,505 square miles of aquatic surface.

The fish fauna is composed of a large number of species most of which occur in fairly large quantities. According to Hildebrand and Schroeder (1928) and Truitt, Bean and Fowler (1929), there are 228 species many of which are highly valued as game fish. The heavy demand on the fishery by sportsmen is due, in part, to the proximity of these waters to large centers of population such as Washington and Baltimore.

The principal fishes of Maryland taken in fresh water are smallmouth and largemouth black bass; "Susquehanna salmon" *(Stizostedion vitreum);* speckled, brown and rainbow trout. The striped bass *(Roccus lineatus),* locally known as "rock," is regularly taken in the estuaries of several large rivers of the Bay. This species also constitutes one of the most important salt water game fish.

As an illustration of the popularity of fresh water fishing the following data, taken from the Annual Reports of the Maryland Conservation Department, may be presented. The number of licenses issued to resident anglers during the period from 1930 to 1935, inclusive, were as follows: 12,270; 11,629; 13,823; 12,761; 15,805; and 17,470. In addition to this, quite a high number of non-resident licenses were issued, namely: 969; 957; 802; 523; 718; and 715, respectively. Moreover, every year about one hundred temporary (three day) non-resident licenses were taken for fishing in Deep Creek Lake. The fee for all these licenses during 1935 amounted to about $20,650.

The sport fishing in Chesapeake Bay proper is much more important than that mentioned for fresh water areas. The principal salt water fishes are as follows: Croaker *(Micropogon undulatus),* locally called "hardhead"; weakfish *(Cynoscion regalis),* commonly known as "trout" or "gray trout"; bluefish or taylor *(Pomatomus saltatrix);* spot *(Leiostomus xanthurus),* and rock. The number of sportsmen fishing in Chesapeake Bay is very high. Unfortunately, up to the present time, very little attention has been devoted to the sport end of the Chesapeake Bay fisheries. The Conservation Department of Maryland, during August of 1932 and 1933, made an attempt to gather data on the

number of anglers fishing in the bay. According to the very interesting figures gathered (1933, pp. 19-20) during the period from August 21 to 29, 1932, over 9,700 people visited the principal fishing resorts of this bay. During the first week of August in 1933, the number of sportsmen was estimated as high as 11,126. Last year, as well as this year, according to personal information, the number fishing in Chesapeake Bay was much higher. It is quite safe to state that annually about 200,000 sportsmen fished in Chesapeake Bay waters with hook and line.

An attempt is now being made to get facts concerning the quantity of fish taken by anglers in local waters. This task, obviously, is exceedingly difficult, hence complete accuracy is hardly to be expected. On the basis of data obtained from two chief sport fishing centers, Solomons Island and Tilghmans Island, some idea on this subject may be gained. At Solomons Island there are about seventy-five motor boats carrying fishing parties. According to local estimates, during the fishing season from the last week of May up to the beginning of November (twenty-one weeks) at least 40,000 people visit this place, taking over 200,000 "hardheads" and about 75,000 "trout." In other words, upwards of one-half million pounds of these species are taken here annually. At Tilghmans, where 65 boats carry fishing parties during the season, which is practically the same as that of Solomons, about 30,000 people fish during a season. The quantity of fish caught at these points is about equal. In addition to hardheads and trout, considerable quantities of rock, bluefish, and spot are taken.

The reputation of Chesapeake Bay as a fishing area grows apace even outside of Maryland. For instance, during the last five years over 60% of the sportsmen fishing at Tilghmans Island were from Pennsylvania.

It is very difficult to estimate how much money is spent along the Chesapeake for rent of boats, bait, fishing tackles, hotel bills, gasoline, etc. Taking as a basis $1.00 per person per trip (Denmead 1935) about $200,000 is paid for rent of boats alone. The price for "peelers" *(Callinectes sapidus)*, principal bait for hardheads and trout, varies from 50 cents to $1.50 per dozen at Chesapeake water front while at Baltimore they are sold as high as $3.00 per dozen. Another very important bait for rock and several other species of fish in Maryland waters is the blood worm *(Nereis)*, the source of which, primarily, is New York and New Jersey. From which states (Fiedler, 1935, p. 190) there is produced annually 10,990 pounds with an estimated value of $9,895. Blood worms sell for approximately thirty cents per dozen in Maryland, where a large part of the total yield is consumed.

In view of the importance of sport fishing in Maryland it is hoped that more attention will be given to gathering accurate statistical data not only on the number of sportsmen, fishing boats, and quantity of fish taken, but also on fishing tackle, bait and other items of sportsmen's expenditure.

It is probable that in other states sharing their fish with some 9,000,000 sport fishermen (Denmead 1935, p. 40) data are likewise inadequate. Hence, it would seem essential that in the near future, more attention be given to this aspect of the fishery throughout the entire country.

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THE RELATIONSHIP OF THE GRAVID PERIODS OF CERTAIN MUSSELS IN MICHIGAN TO THE PEARL BUTTON INDUSTRY

HENRY VAN DER SCHALIE

Museum of Zoology, University of Michigan, Ann Arbor, Mich.

In Michigan, the pearl button industry is decidedly limited in its scope. This is largely because of two important factors. In the first place, there are relatively few mussels in the state which can be used commercially. Most important of these are the Mucket *(Actinonaias carinata)*, the Pocketbook *(Lampsilis ventricosa)*, and the Three Rib *(Amblema costata)*. Others of commercial importance are listed in Table 2. In the second place, the species used by the industry are limited in distribution to streams in the southern part of the southern peninsula; i. e., to those streams in the region of and south of the Saginaw-Grand valley. The reasons for this are connected with glacial history and need not be discussed at this time.

Considered in relation to the size of the industry in certain states (such as Wisconsin, Illinois, Indiana, and Ohio), the mussel industry in Michigan has been comparatively small. As in other states it has had a similar history in that at one time mussels were abundant in the more productive streams, but by intensive collecting, pollution in certain areas, power-dam developments, etc., we have reached a stage where mussels for commercial purposes are scarce. In order to give some idea of the present status of the industry in Michigan, the accompanying data[1] are presented (Table 1). From the table we may note the size of the industry in terms of the number of people engaged in gathering the shells, the number of pounds of shell taken, and the value of the raw material. Unfortunately, we do not have for comparison similar figures compiled at a time when the industry was at its best in this state. Such a comparative table would no doubt indicate that the figures for the past five years are but a small fraction of what they once were. For comparison there is, however, a figure in a Bureau of Fisheries Document (972) which lists 4,825,170 pounds of shell taken from Michigan streams in 1922, with a value of $191,161 (including the value of pearls). Furthermore, there is a statement in the Biennial Report of the Department of Conservation for 1929-1930 (p. 208) which estimates: "The value of the output probably exceeds $500,000 annually."

In view of the marked depletion of the mussel population, certain laws[2] have been enacted presumably with the idea of protecting the "spawning" mussels. These laws provide for open and closed seasons,

[1] These data are taken from the Seventh Biennial Report (1933-1934) of the Fish Division of the State Department of Conservation.

[2] Laws Relating to Conservation, State of Michigan, Revision of 1935, pp. 70-73.

TABLE 1. MUSSELS TAKEN FROM MICHIGAN WATERS

	1930	1931	1932	1933	1934	1935
Number of licenses issued	2,460	522	392	822	1,362	190
Number of pounds of shells taken	1,753,500	1,503,511	1,543,358	2,950,229	1,746,623	*
Value of shells	$34,472.52	$27,376.06	$21,059.24	$85,309.16	$32,427	*
Value of slugs and pearls	$3,206.50	$2,546.64	$884.33	$2,555.55	$1,228	*
Total value	$37,679.02	$29,922.70	$21,943.57	$87,864.71	$33,655	

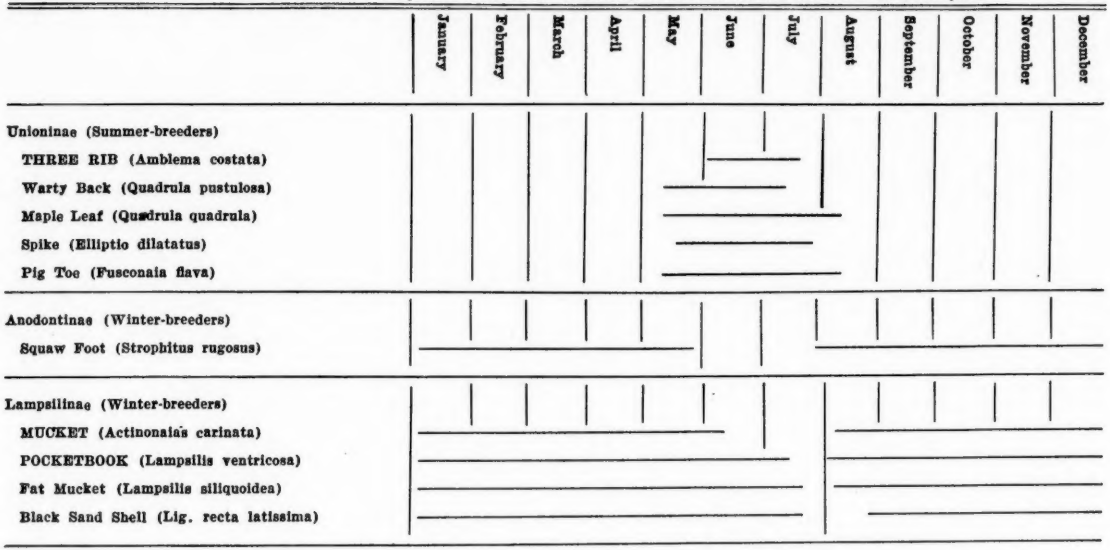
* Figures not available.

much as such seasons are provided for by fish and game laws. Since there is still much to be learned regarding the "spawning" seasons of our freshwater mussels, it would not be surprising to find that closed seasons fixed by law do not actually correspond with the natural spawning period. Data on the gravid periods of Michigan mussels, gathered over a period of several years, have led the writer to the conclusion that it would be of interest to present the available information, and, on the basis of it, to make recommendations which may be worthy of consideration.

The fact that our local species of mussels may be grouped into two major divisions on the basis of their breeding season is generally known. These two groups are referred to in various ways, though essentially the terms have the same meaning. We may refer to one group as *short-term breeders, summer breeders,* or *tachytictic species;* to the other as *long-term breeders, winter breeders,* or *bradytictic species.* For convenience we shall refer to them in this paper simply as *summer breeders* or *winter breeders.* To define these terms more specifically, the summer breeders propagate usually during some period within the months of May, June, or July; while the winter breeders usually become gravid in late summer and fall, and as a rule carry the larvae (glochidia) through the winter to be set free when the waters become warmer in April, May, or June.

The gravid periods of the mussels of commercial importance in Michigan are shown graphically in Table 2, in which species have been grouped in accordance with the outline just given. The names of three species in this list, namely the Three Rib, the Mucket, and the Pocketbook, have been capitalized, since reports on file at the office of the Conservation Department indicate that these kinds are most desirable for commercial purposes, and constitute the bulk of the shell material gathered each year. As a result, we must consider them of prime importance. From Table 2 we note that the Three Rib is gravid during June and the early part of July. The open season in Michigan does not begin till July, so that this species is perhaps fairly well protected by law. However, the case is quite different when we consider the Mucket and the Pocketbook. They both become gravid early in August, so that

TABLE 2. TABLE SHOWING GRAVID PERIODS OF MUSSELS OF ECONOMIC IMPORTANCE IN MICHIGAN



they are not fully protected by the law. In fact, with the open season during the months of July, August, and September, these species are taken in the gravid state during two-thirds of the season. They are of such outstanding importance that it would even seem advisable to protect them without regard to the gravid periods of the other species.

Through the kindness and cooperation of Mr. Fred A. Westerman and his staff at Lansing, permission was granted to examine the annual reports submitted by mussel fishermen operating under state licenses. Because of insufficient time, the reports for 1934 only were considered in detail. The data taken from these 1934 reports may be summarized as follows: of the 1,362 individuals to whom licenses were issued, approximately 542 sent in reports, of which 113 contained statements that would give some indication as to the concensus of opinion among the fishermen on matters pertaining to the industry. Many complained about the small amount paid for the mussels by the buyers. Practically all indicated that the supply had been much depleted, and that as a consequence it was difficult for them to earn sufficient to compensate them for their efforts. A relatively large proportion (fifty-nine out of the 113) felt that this depletion should be remedied by closing the mussel-producing streams for a period which varied from three to five years. It was of special interest to find that several suggested that the open season should be shorter, so as to protect the gravid specimens in August and September.

In conclusion, it may be stated that both the scientific information available regarding the gravid periods of mussels of commercial value and such information as has been submitted by the mussel fishermen themselves, indicate that the season for clamming would need to be restricted to the month of July, in order to provide a seemingly adequate protection for the most valuable commercial species during the spawning season.

The conservation measures now applied are apparently based on the assumption that keeping the spawning season closed to clamming sufficiently protects the mussels. If this is true, it is but logical that we curb the open season as indicated above; by limiting that season to the month of July. However, it is very questionable whether such a measure will be effective in conserving the mussels. The perpetuation of organisms that have a life-span of only one or a few years may be insured by protecting the adults during the spawning season. However, in a group, such as the mussels, whose life span is so long that successive batches of young are produced over a period of a considerable number of years, it would likely make but little difference whether adults are taken before, during, or after the breeding season. A mussel taken before the spawning season contains germs of eggs which would probably otherwise have matured during the following spawning season, and also for several years in the future. Destroying these undeveloped eggs is almost as effective as the destruction of the mature spawn. We can go

even a step farther and question whether closing a stream for a short period (one to five years) would constitute a suitable conservation program for a group that has so long a life-span, and that reaches suitable marketing size as slowly as mussels do; for in so short a period no great amount of growth would result.

The conservation of the mussel supply would seem from the biologist's viewpoint to involve first of all a control of silting and pollution, for the mussels are particularly susceptible to these destructive influences. When regulations are required to maintain a heavily-fished stock, the logical course would seem to be a simple limitation on the quantity that may be cropped in each area without depleting the supply. Determining the safe crop from year to year would require the services of a trained investigator, who would follow the fluctuations in supply and yield by such methods as are employed in modern fisheries management. He would estimate the population by biological samples, and follow the yield by the analysis of detailed catch records. This would insure the conservation of the fauna and assure the industry of a future.

THE WARNER-BOWER FISH CONVEYOR

E. A. Bower

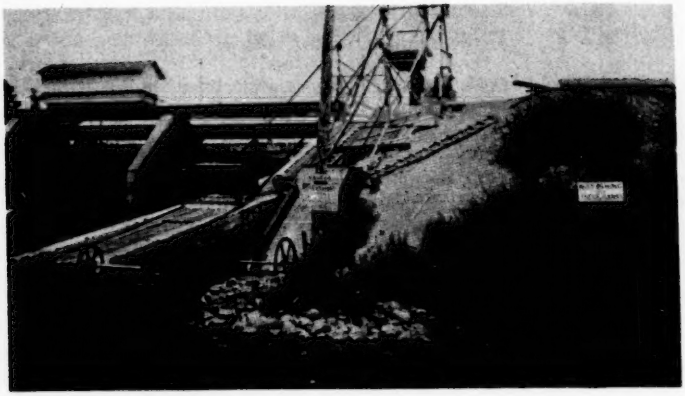
Benton Harbor, Mich.

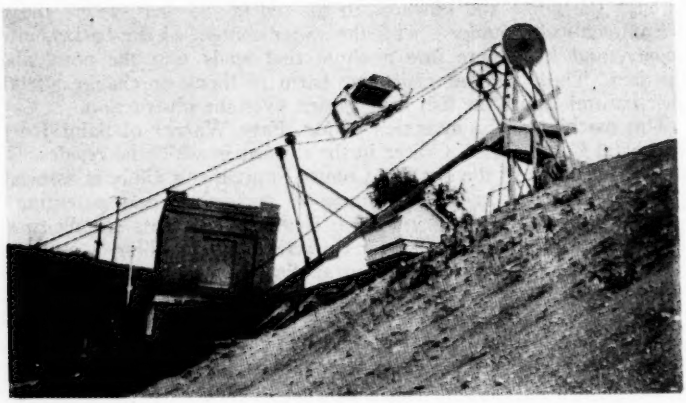
Aiding the processes of natural laws by electricity is the idea behind the Warner-Bower Fish Conveyor. It is generally known that many fish annually migrate during the spring spawning season into the upper reaches of streams where they deposit their eggs. Modern industrial methods which call for the development of many uses for electric light and power and consequently the construction of thousands of dams, have impeded the operation of this particular natural law. Strangely enough, this same industrial development has brought its own remedy for the removal of the impediment. By the use of electric power the fish may now be aided in their response to instinct and may even be helped along their way.

Assisting fish with the Warner-Bower Fish Conveyor does not in any way change their natural habits. When fish come to the base of the dam, seeking further advance, they meet a flume through which is coursing a swiftly moving stream of water which by its rapidity of movement attracts them away from the more sluggish waters. As they go into the flume, the specially-devised machinery causes a basket to enter the lower mouth of the flume. In this basket, as in a dip-net, the fish are trapped. As the machine continues to operate, this basket is raised through the flume and upwards to the top of the dam, where the fish are automatically dumped, with the water content of the basket, into a hopper, and from here into a chute that leads into the pond above the dam. Thus, without resistance harm to them, or change affecting their natural habits the fish have gotten over the obstruction.

This machine is the invention of Mr. Faye Warner of Saint Joseph, Michigan, Conservation Officer in the district in which he resides. The author, president of the Berrien County Sportsmen's Club, is associated with Mr. Warner in the development, perfecting, and patenting of his device. Mr. Warner's invention is attractive by its simplicity and effectiveness but most of all by its practicability in filling a real need.

Even while Mr. Warner's patent application was pending and to assure themselves of the success of their machine in actual operation, Mr. Warner and the writer constructed one and placed it on the municipal dam at Union City, Michigan, where it was operated from May 16, 1936 until June 16, 1936. Here it has been inspected by many people, particularly those interested in industries that utilize water power and conservation men from many estates. The record made by the machine speaks for itself. While it was too late to obtain data for the heaviest part of the spring run, nevertheless the results disclose that after the middle of May, the fish conveyor carried 1503 fish in





Two views of the Warner-Bower fish conveyor in operation at Union City, Michigan.

62½ hours of actual operation. The logue, tabulated by the operators of the dam and on file with the City Clerk at Union City, is as follows:

Date	*Dips*	*Total Fish*
May 16, 1936	15	339
May 18, 1936	1	24
May 19, 1936	3	49
May 20, 1936	1	31
May 21, 1936	2	32
May 22, 1936	1	7
May 23, 1936	1	8
May 24, 1936	1	29
May 26, 1936	5	24
May 27, 1936	1	14
May 28, 1936	3	15
May 30, 1936	1	6
June 1, 1936	1	2
June 2, 1936	1	82
June 3, 1936	10	303
June 5, 1936	7	151
June 6, 1936	7	187
June 7, 1936	4	92
June 13, 1936	2	51
June 14, 1936	1	26
June 16, 1936	1	31

The fish consisted of one bull-head, two northern pike, sixteen black bass, fifteen suckers, thirty-five sun fish, fifteen ship-jacks, and 1,419 blue gills. There are no trout in the river at this point.

The time required for a complete revolution of the basket from flume and back to flume again is from twelve and one-half to fifteen minutes, depending on the distance the flume rests from the top of the dam. The fish are in the basket approximately four minutes. The hopper at the top of the dam from which the fish go into the chute is closed by a gate. In this hopper the fish are never out of the water, but can be counted, inspected, and sorted, and the obnoxious fish removed before the gate is opened permitting fish to slip on into the pond.

The Warner-Bower Fish Conveyor can be adapted to a dam of any size or a stream of any width, regardless of the depth of the water. The conveyor is so situated in the bottom of the stream as to free it from danger of damage by ice during the spring freshets. The flume may be built of concrete and form a part of the dam itself in the case of new construction, or it may be of steel. It can be attached to any existing dam. It can always be so installed over the face of any dam, new or old, that it will not interfere in any way with the construction of the dam or with the use to which the dam is put. It can be built any width

necessary to enable it to carry more fish. Such construction calls merely for a longer or wider basket and heavier machinery. The ascent of the basket can be gradual or steep; the pitch of the dam has no effect on the results that may be expected. The conveyor needs no attendant.

The Warner-Bower Fish Conveyor is the answer to an acute and burning question to which Nature, outraged by interference with her ceaseless processes, has long demanded from Industry its reply. And in replying, Industry has said to Nature:

"Go thy way! I have designed especially for you and presented to you one of our modern conveniences, one that is adapted to your requirements, with no attempt to change the natural instincts of your migratory fish."

Discussion

Dr. Hubbs: How much variation in the level of the tail water can you accommodate with this machine? You have to have your flume low enough to be below the lowest level of the tail race?

Mr. Bower: Of course at that time there would be no fish migration.

Dr. Hubbs: Will any variation in the level above modify the action of your carrier?

Mr. Bower: No, because the entrance to the spillway leading into the flume would be even with the lower part of the gauge to the dam.

Dr. Hubbs: There would be no danger of logs floating down and injuring the apparatus, because the upper end is on top of the dam?

Mr. Bower: Yes, entirely on top of the dam.

A delegate: How do fish return downstream over the dam?

Mr. Bower: Fish, other than salmon, seldom attempt to pass down over a dam, seemingly being satisfied with the lake or reservoir in which they find themselves on their return downstream after spawning. Young salmon pass readily over a spillway, or through a turbine without any seeming injury.

COMPOSITION AND UTILIZATION OF THE ATLANTIC WHITING, *MERLUCCIUS BILINEARIS*[1]

D. A. Bean, J. A. Clague and C. R. Fellers

Massachusetts State College, Amherst, Massachusetts

Probably no fish is marketed under such unusual conditions as the Atlantic whiting, *Merluccius bilinearis,* often referred to as the silver hake. Although practically the entire catch of whiting is made along the Atlantic Coast from Cape Cod to New Jersey, yet nearly one-fourth of the total supply is distributed in St. Louis, some 800 or more miles from the source of supply. There the whiting are sold in hot fish shops, which, according to Johnson (5) have increased from one to about three hundred during the past twenty years. Yet, in the interior of Massachusetts, the state where most of the whiting are caught, there are very few people who have even heard of the fish. A variety of fish which is in such demand in the middle West, where fish consumption is at a minimum, must have qualities which should make it more generally popular.

Most of the whiting are caught in pound nets, floating traps and weirs at a short distance from the shore although considerable quantities are now caught by otter trawls. They are brought in and frozen the same day they are caught, since the freezing plants are ordinarily located near the fishing grounds. The extent of the frozen whiting industry is shown by the Bureau of Fisheries Bulletin on "Cold Storage Holdings of Fish," July 15, 1936. The total holdings of frozen whiting were 12,117,447 pounds, almost 3,000,000 pounds more than that of any other fish.

The object of this investigation was to study methods for better preserving and utilizing the whiting as a food product. Chemical analyses were made on the flesh and on the liver oil to show the value of the species as a food fish and as a possible source of vitamins.

Review of Literature

Very few studies on whiting have been reported in the literature. Tressler (6) states that some work was done on the utilization of whiting during the World War. An interesting survey of the use of whiting in the hot fish shops of St. Louis has been given by Johnson (5). Clark and Almy (2) determined the percentage of fat, ash and nitrogen partitions in the whiting as well as the body oil constants. No complete analyses of whiting flesh nor vitamin A and D values apparently have been reported previous to the present study.

[1] Contribution Number 254, Massachusetts Agricultural Experiment Station.

Preservation Studies

In the following summary of the work on preserved whiting products no attempt is made to give in detail the canning procedure. It is hoped, however, that the information given will be sufficient to enable any interested person to duplicate the results. Most of the products were canned in pint glass jars as well as in tin cans, so that the formulas can be applied to home canning, it being necessary to add twenty minutes to the processing time given for the one-half pound tin cans.

In all instances where the products were packed in tin, "C" enamel cans were used, since this type of enamel prevents sulfide blackening in marine products.

The receipts and formulas given in this paper are basic only and it may be found desirable to alter them to suit individual tastes.

For more detailed information on fish canning see the U. S. Bureau of Fisheries bulletin by Jarvis and Griffiths (4) from which some of the formulas used here were adapted.

Freezing

All the fish used in the following experiments were frozen in commercial freezers on Cape Cod and were in excellent condition. The fact that so much of the total catch of whiting is marketed frozen is ample proof of its suitability for preservation by freezing. The whiting may be held for several months when solidly frozen. However, because of its small size it dries out rather quickly and loses its fresh appearance unless occasionally glazed.

Canning

The frozen fish were thawed at room temperature, the procedure taking about 6 to 8 hours. They were then washed, scaled, eviscerated, and filleted. The fillets were placed into a six per cent brine, and soaked for an hour. The fish were removed from the brine, drained for a few minutes and then cut into container length pieces and packed into glass jars or one-half pound cans. The jars were then sealed and processed for 110 minutes at 240° F. (ten pounds steam pressure).

Other lots of fish were sealed under a vacuum of fifteen inches of mercury in one-half pound "C" enamel cans. These cans were processed for ninety minutes at 240° F. and cooled immediately in cold water.

Fish Flakes

The procedure in this case was to cook the whiting fillets in boiling water for 15 minutes, cool, and flake the meat. The whiting flakes were packed into one-half pound cans, sealed under vacuum and processed for ninety minutes at 240° F.

Fish Chowder

The fish were beheaded, eviscerated, covered with water and boiled until thoroughly cooked. After cooling, the fish flesh was separated from the skin and bones. The latter were covered with fresh water and simmered for one and a half hours in a covered kettle.

Ingredients used in the fish chowder were:

Diced potatoes	4 pounds
Prepared fish	3¼ pounds
Onions	1¼ pounds
Salt pork	1¼ pounds
Salt	3¼ tablespoons
Pepper	2 teaspoons
Fish broth	3 quarts

The pork was cut into one-half inch cubes and browned in a frying pan. The chopped onions were added and cooked until they were light brown in color.

Old potatoes, or those which have been in storage for a few months are better than new ones for use in chowder because they do not darken so readily. The potatoes were cut into cubes and added to the rest of the ingredients. Everything was thoroughly mixed together and filled into one-half pound cans. The product was sealed under vacuum and processed for ninety minutes at 240° F.

Whiting in Tomato Sauce

Whiting with tomato sauce was one of the best canned products prepared in this study. The sauce consisted of the following materials:

1	gallon tomato puree
6	tablespoons spiced vinegar sauce
½	ounce ground horseradish
2	tablespoons minced onions
1	ounce salt

The ingredients were mixed and concentrated by boiling to one-half the original volume. The fish were beheaded, cleaned, scaled and pieces of fish cut to fit the can. The sauce was poured over the fish. The cans were sealed and processed for ninety minutes at 240° F.

The spiced vinegar sauce was made up as follows:

2	quarts vinegar (preferably distilled)
1	quart water
2	ounces sugar
¼	ounce whole white pepper
¼	ounce mustard seed
¼	ounce whole cloves
⅛	ounce cracked cardamon seed
⅛	ounce cracked whole ginger
⅛	ounce bay leaves

The sugar, water, and vinegar were mixed together and the spices tied in a cheesecloth bag were added. The mixture was simmered, but not boiled, for an hour.

This spiced vinegar sauce was also used in the manufacture of a canned spiced whiting, but the product was not satisfactory and so details of the manufacture are not given.

Fish Cakes

The whiting were filleted, skinned, cooked and run through a food chopper. Cooked, mashed potatoes and chopped onions were added in the following proportions:

¾ pound onions
4 pounds prepared fish
5 pounds potatoes

Salt and pepper to taste were added and all the ingredients were mixed together with enough water to give the proper consistency. The mixture was packed into one-half pound cans, sealed under a vacuum of fifteen inches of mercury and processed for seventy minutes at 240° F.

Smoked Whiting

While whiting is not commercially smoked at the present time, Fiedler (3) states that fifty pounds were smoked in 1933. Methods of smoking are not given. At any rate the industry is relatively unimportant.

The fish for these experiments were cleaned, filleted and all blood spots were removed. A ten per cent salt solution (41° salometer) was prepared and the fillets were immersed in it for ninety minutes.

After brining, the fillets were hung up to drain overnight, the object being to prevent streaking of the fillets during the smoking process. Tests were made to determine the best conditions for smoking. Corn cobs were used as a source of smoke for the first lot of fillets. The temperature of the smoke-house was about 100° F. Samples were taken out at four and one-half, six and eight hours.

Since corn cob smoke seemed to produce a rather dark fillet, hardwood sawdust was used as a source of smoke for the other lots of fillets. Samples were taken out at four and five and one-half hour intervals.

When the corn cobs were used for the smoke, the four and one-half hour treatment gave the best product. However, a five and one-half hour smoke using hardwood sawdust was considered the best procedure of several tried. There was a loss of approximately twenty per cent in weight during the brining and smoked operations.

The smoked whiting was held for two weeks at a temperature of 34° F. and was still in good condition.

Canned Smoked Whiting

Several types of canned smoked whiting were packed. The smoked fillets were skinned, and cut into lengths to fill one-half pound cans. Some cans were filled with cottonseed oil, some with olive oil, some with one ounce of water added, and others had nothing added other than the fish. The cans were sealed under a vacuum and processed for seventy minutes at 240° F.

Discussion of Preserved Products

The smoked whiting was the outstanding preserved product. It had reasonably good keeping qualities, and when properly cooked was decidedly tasty. Canned smoked whiting was also a good product. Of the different packs canned, the plain smoked whiting and the smoked whiting canned with olive oil were the best.

Canned fish cakes made with whiting were a very satisfactory product as was also the fish chowder, although the latter product darkened somewhat.

Whiting canned with tomato sauce was a good product but the tomato sauce had a somewhat scorched flavor. No doubt, refinements in packing and processing would greatly improve the product.

Plain canned whiting and whiting flakes were the least desirable of the products made in this study.

There would seem to be distinct commercial possibilities for greater utilization of the whiting by manufacture into several desirable smoked or canned products.

Chemical Composition of the Whiting

A proximate analysis, as well as determination of calcium, phosphorus and potassium, were made on a sample of whiting prepared as follows: The fish were beheaded, eviscerated and cleaned. They were then ground in a meat chopper and dried in an oven at 100° F. After drying the fish was further ground up in a mill.

Determinations were made according to the official methods of the A. O. A. C. (1). Results are shown in Table I. Compared with white fish meals, those made from haddock and cod, the whiting is much higher in protein and fat but is lower in ash. The ash is low in calcium and phosphorus content but is high in potassium.

Liver Oil

The whiting liver oil was extracted from the ground up liver by cold ether extractions. The ether was distilled from the oil-ether mixture and the oil was used for later vitamin studies. The livers contained forty per cent oil, but only thirty-one per cent was obtained by the cold extraction method.

The refractive index of the oil was 1.471 and the specific gravity 0.920.

Vitamin A Content of Liver Oil and Flesh

The ether-extracted whiting liver oil was also assayed for vitamin A content. The oil was fed at the 0.1, .01, .002 and .0005 gram levels to separate lots of seven young rats in strict accordance with the U. S. P. technic (7). At the .0005 gram level the rats gave an average individual weight gain of sixteen grams for the four weeks test period. By comparison with standard U. S. P. reference oil the whiting liver oil showed the high value of 2,770 units per gram, or several times richer than cod liver oil.

The raw frozen whiting flesh was similarly assayed for vitamin A content. Levels of 0.5, 1.0 and 3 grams were fed groups of seven rats with resulting weight gains of 14.4, 18.4 and 39.3 grams, respectively. The vitamin A content is thus estimated at from two to five units per gram of flesh. Of course the oil content is very low, being approximately two per cent.

Vitamin D Content of Liver and Body Oil

In the vitamin D study the U. S. P. (7) method of assay was used. The whiting body oil was extracted from the flesh in the same manner as was the liver oil. For feeding purposes, both oils were diluted with salad oil to definite concentrations. Only 0.1 gram portions were fed.

TABLE 1. CHEMICAL COMPOSITION OF WHITING

Ingredient	Composition of Whiting Meal as Prepared for Analysis	Composition of Whiting Calculated on a Wet Basis	Composition of Whiting Calculated on a Dry Basis
	Per cent	Per cent	Per cent
Moisture	5.55	81.3	....
Fat	9.73	1.99	10.3
Protein (N x 6.25)	81.48	16.65	86.27
Ash	5.29	1.07	5.60
CaO	.32	.065	.34
P_2O_5	2.03	.42	2.16
K_2O	1.76	.36	1.86

The body oil was found to contain approximately the same amount of vitamin D as the reference cod liver oil, that is ninety-five U. S. P. units per gram.

Whiting liver oil had at least 950 U. S. P. units of vitamin D per gram, a very high value. The eight rachitic rats fed this oil at the .0001 gram level showed average weight gains of nine grams and all gave three-plus calcification (line tests) of radii and ulnae.

It appears that whiting liver oil is a very rich source of both vitamins A and D. Although the size of the fish and its liver are relatively small, still the high vitamin content should make commercially feasible the extraction of the liver oil.

Conclusions

1. Smoking was found to be the most satisfactory method of processing the whiting.
2. Of the canned products tested smoked whiting canned either plain or in olive oil, fish chowder, fish cakes, and whiting in tomato sauce were outstanding.
3. A proximate chemical analysis of the edible whiting flesh (moist basis) showed it to contain 81.3 per cent moisture, 1.99 per cent fat (ether extract), 16.65 per cent crude protein and 1.07 per cent ash.
4. Whiting flesh contains two to five U. S. P. units of vitamin A per gram.
5. Whiting liver oil is a very rich source of vitamins A and D. The vitamin A content was 2770 U. S. P. units per gram; the vitamin D content was approximately 950 U. S. P. units per gram.

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SAMPLING ERRORS IN CALCULATING THE WEIGHT OF FISH IN PONDS

C. McC. MOTTLEY

Pacific Biological Station, Nanaimo, B. C., Canada

The pond culture of game fish is becoming a far more businesslike undertaking, due largely to the pioneering efforts of Embody, McCay and Tunison to improve the feeding technique. One of the outstanding achievements in recent years has been the scientific preparation of diets. An important phase of this development is the attempt to feed the prescribed diets on the basis of a percentage of the total weight of the fish in a pond. The determination of the total weight of the stock of fish on hand, therefore, becomes an exceedingly important calculation. In experiments conducted on a small scale it is a relatively easy matter to remove all the fish in a given lot and weigh them; the quantity determined, while open to certain difficulties involved in the technique employed, is a definite value, neither more nor less than the amount stated. On the other hand, it is a practical impossibility to dip out and weigh all the fish in a large production unit every two weeks in order to determine the amount of food required. The alternative is to take a sample and calculate the total weight from the value so obtained.

When sampling is resorted to it is not merely enough to weigh a pound or so of fish and calculate therefrom the total weight: sampling is a complicated statistical procedure and the adequacy of a sample depends on the accuracy of the data required. As far as the writer is aware no one has published any data on the errors to be encountered in sampling fish from ponds, although the procedure has been adopted in many production plants. Aside from the difficulty of obtaining a truly unbiased or random sample, the main problem is to determine how big a sample should be taken in order to provide a sufficiently accurate idea of the total amount of fish in the pond. It is the purpose of the present paper to draw attention to the fact that small samples are almost valueless and may even lead to an entirely erroneous determination in large scale operations.

In a paper presented before this Society last year the writer mentioned that there was a considerable discrepancy in the size of fish as determined from samples collected by the use of a dip-net as compared with a random sample taken by selecting one in a certain number, e. g. one in a hundred. The latter method, which was considered to be more representative, gave a value about 5 percent higher than the former. Recently data have come to hand to substantiate the observation that the bigger fish tend to occupy the upper end of the trough or raceway. This habit, coupled with the tendency for the bigger fish to avoid the

dip-net, makes the problem of securing a representative sample a very difficult one. If a high proportion of the small fish are caught then the amount of food necessary is liable to be underestimated; if too many large fish are sampled then wastage may result.

Another important consideration is the accuracy with which the number of fish placed in the ponds at the beginning of operations was estimated. If there was a serious error in this determination any subsequent calculations may likewise be affected. It is also essential that an exact record be kept of the losses. Unfortunately it is a common practice among "the old hands" to guess at the losses. The writer has found it a good rule to have all the dead fish picked out of the ponds and preserved in bottles. It is a relatively easy matter to check up losses that are guessed at by determining the proportion of the final digits in the numbers recorded. Theoretically there should be 10 per cent of each of the digits from 0 to 9 in figures higher than 20 or 30 that are recorded at random. Guesses have a pronounced tendency to fall on the 0 and 5.

If the foregoing requirements have been satisfactorily met then the problem becomes primarily one of the adequacy of the sample. A good opportunity for studying this question was afforded in March, 1936, at the time of releasing the brown trout reared at the Qualicum Beach ponds of the Provincial Game Department. These ponds are of the "raceway" type. In order to avoid cannibalism the fish were graded and all the small ones were segregated in a separate pond. At the end of the season all the fish were hand-counted out in order to give an absolute check on the efficacy of the grading technique. A total of 48,878 brown trout averaging about 3 inches in length was dipped out of the ponds in samples weighing approximately three pounds on the average. This affords 214 samples on which the present paper is based.

Method

The fish were dipped from the pond with the water running but with the level lowered to a foot or less, a wire meshed dip-net being used for catching the fish. They were retained in a basket resting in a short trough. From this holding-basket they were transferred one, two, three, at a time in the palm of the hand to a second basket. Each fish was registered on a tally machine. When the holding-basket sample was completely counted into the second basket the latter was lifted from the trough and allowed to drain for a few seconds. The fish were then placed in a bucket containing a known weight of water. The weight of the fish to the nearest quarter of a pound was then noted. The recorded weights were thus subject to an error of about 4 or 5 per cent which was considered to be accurate enough for live weight determinations.

With these two determinations, the total number and the total weight of each sample, the number of fish per pound was calculated. The num-

ber per pound is not only a convenient figure to work with, but is the most readily understood by fish culturists. If the average weight of the fish is desired it is an easy matter to convert the number of fish per pound into average weight per fish by turning up a table of reciprocals and using the reciprocal values. For instance 60 fish per pound gives an average weight of .0167 pounds.

The Data

The fish in three of the ponds were approximately of the same size whereas the fourth contained the small fish that had been previously graded out. Table I gives the condensed data for the number of fish per pound in the four ponds. The data were grouped in intervals of five: all the values from 51 to 55 inclusive are grouped as 53; all those from 56 to 60 inclusive are grouped as 58 and so on. The average number per pound given at the bottom of the table will be found to differ slightly from an average that may be calculated from the numbers in the table. The former is the true value based on the ungrouped data. A statistical measure of the variation of the several samples, known as the standard deviation, was calculated and is also given. The standard deviation is merely a mathematical yard-stick for measuring the scatter of the observation around the true average. It will be found as the discussion proceeds below that it is an extremely valuable statistic to understand.

Discussion

Normally the fish culturist does not know what the total weight of the fish in his pond is. He knows or should know within fairly narrow limits what the total number is. If he counts and weighs all the fish then there are no unknowns. The fish culturist, however, does not wish to undertake the labour involved in such complete determination. His problem is to weigh as many fish as will give him an accurate idea of the weight of the stock on hand.

With normal expectations in the case of pond number 3, which averaged 68 fish per pound, a single sample similar to those taken and recorded in Table I would have fallen anywhere between 88 and 53 per pound. This statement is based on the assumption that only once in 22 trials will twice the standard deviation be exceeded. This limit is usually taken as being within reasonable probability. Suppose that a sample were taken and it happened to fall near the upper limit, 88 fish to the pound. This would give the total weight of the fish in the pond as 165 pounds whereas it is definitely known that the total weight was 214 pounds. A sample that happened to fall near the lower limit would have placed the total weight of the fish at 265 pounds. It is apparent therefore that samples of about three pounds could give an estimate with a very wide range. In this case it is quite possible for a single sample of about three pounds to give an estimate of the

total weight of fish in the pond anywhere within 24 per cent of the true value.

If, as Tunison and McCay recommended, fish of this size be fed daily an amount of food equal to 5 per cent of their body weight, then two such widely divergent samples would give values as extreme as 8 and 13 pounds of food per day. It is obvious that such values are too far apart to be of much value in calculating the amount of food required. A good fish culturist could judge from experience how much to feed with greater efficiency.

In order to be of real service to the practical fish culturist he should know approximately to the pound how much food should be fed to fish of this size in ponds of this type. How big a sample should he take in order to calculate this value? In a pond containing 214 pounds of trout he should be feeding daily about 10.7 pounds of food, or for practical purposes 11 pounds. He should not feed less than 10.2 nor more than 11.2 pounds to be within the limits of his requirements. To fall within these limits his estimate of the stock of fish must lie therefore between 205 and 225 pounds.

In order to convert these values into terms of the number of fish per pound, to arrive at the limits of twice the standard deviation, it is necessary to refer to the total number of fish in the pond. A total weight of 205 pounds with a total number of 14,609 fish gives a value of 71 fish to the pound, similarly 225 pounds gives a value of 65 fish to the pound. This means that the upper and lower limits of twice the standard deviation must be 71 and 65, or that the standard deviation must be reduced to about 1.5 in order to give an estimate of the total weight that will be within the limits of accuracy required by the fish culturist.

In order to obtain a sample that would give such a degree of accuracy it would be necessary to sample about half of the fish in the pond. This is clearly not a practical possibility. The next question then is to determine what degree of confidence may be placed in a sample of a reasonable size.

The data given above were combined into samples of about 30 pounds of fish which was considered to be within the limits of practicability. Pond number three, for instance, provided 7 of these larger samples. It was found that about once in three trials the sample would fall outside of the required limits of accuracy. It is apparent that a good deal of care must be taken in making a calculation from samples even of this size.

Conclusion

It may be concluded from the foregoing data that a great deal of care must be exercised in taking a sample from a pond in order to calculate the total weight of fish that it contains. The sample should be as unbiased as possible; every precaution should be taken not to select

the large or the small fish. It is suggested that more uniform samples might be obtained by turning off the water in the ponds and allowing the fish to become thoroughly mixed before the sample is taken. A series of small samples might be taken and the fish returned to the pond without affecting the results. This procedure was not followed, however, in making the present study. Under these conditions a sample amounting to about one-seventh of the total number of fish in the pond would seem to be adequate to provide an estimate of the total weight of the fish so that the amount of food to be fed can be calculated within 10 per cent of the true value. An experienced fish culturist, however, could probably determine the amount of food required within limits almost as fine as this by noting carefully how much the fish will eat without leaving any waste.

TABLE 1. THE NUMBER OF FISH PER POUND IN THE FOUR PONDS STUDIED

No. per pound	No. of Samples Pond No.			
	1	2	3	4
53	5	1	1	..
58	11	1	5	..
63	18	11	20	..
68	21	22	20	..
73	9	14	14	..
78	3	2	3	1
83	..	..	2	2
88	..	..	1	2
93	..	..	..	6
98	..	..	..	4
103	..	..	..	9
108	..	..	..	5
113	..	..	..	1
Total No. of samples	67	51	66	30
Av. No. per lb.	65.59	69.47	68.19	98.69
Total No. of Fish	14,052	12,297	14,609	7,920
Total Weight	214.25	177.00	214.25	80.25
Standard Deviation	6.27	4.78	6.46	8.60

THE FACTORY SHIP—ITS SIGNIFICANCE TO OUR WORLD TRADE AND COMMERCE

R. H. FIEDLER

Chief, Division of Fishery Industries, U. S. Bureau of Fisheries, Washington, D. C.

INTRODUCTION

In the early days of the sea fisheries which were conducted from our colonial ports, most of the catch was taken by small vessels operating close to shore. The catch was landed fresh. With a decline in the production of the inshore fisheries, the vessels began fishing farther and farther from the home port to obtain a catch. Therefore, it became necessary to use larger vessels and to process the fish by some means to preserve the catch until arrival at port. These obstacles were overcome largely by the use of the so-called "factory ship." As used in this discussion, factory ships are vessels or other mobile units capable of operating over a wide area of the ocean. Some have equipment on board for salting fish, or machinery for canning fish. Others are equipped to freeze fish or to reduce fish and other marine animals into meal and oil. Some perform only the simple processing function of eviscerating the fish and packing them in ice. As a general rule, these vessels operate as a "mother ship"; that is, the fish are delivered to it by smaller craft, known as "catcher" boats, and are processed in some manner on board the vessel. Some of the mother ships may actually engage in the capture of the fish processed on board.

The idea of the "factory ship" is not new, for several types of processing have been done on board fishing craft for centuries. As early as 1517 or 1519 (Jefferson, 1791) the Biscayan fishermen of Spain and the Bas-Breton fishermen of France were engaged in catching fish, usually cod, off the coasts of the now called Newfoundland, Nova Scotia, and New England. These fish were salted on board the vessel and carried back to France and Spain where they were in brisk demand as well as in various other countries of Europe. By 1577 the French had 150 vessels of this type operating in the above mentioned waters; the Spanish, 100; the Portuguese, fifty; and the English, fifteen.

Even to this day the French and Portuguese continue to prosecute this fishery. Each spring vessels from these two countries proceed to the Grand Banks off Newfoundland, returning each fall to their home ports with fares of salted fish. Some French vessels now preserve the catch on board in a different manner, as will be explained later.

The colonization of America is indebted largely to the exploitation of our coasts by these floating salteries, or "factory ships." The ventures usually were profitable, thus leading to an increase each year in the

number of vessels engaged in the fishery. Later, some of the fishermen cured their catch on shore, leading to the development of colonies at the shore stations in Newfoundland, Nova Scotia, and at points farther south.

Sabine (1852) in his writings on American fisheries, was inclined to believe that the Plymouth colony was established by the Pilgrim fathers in 1620 not only for the purpose of obtaining religious freedom but also for the purpose of forming a fishing colony. Prior to their departure for the New World, the Pilgrims had spent ten years in Holland after leaving England. While in England they no doubt learned much about the fisheries in the Western Atlantic from the accounts of English explorers operating along the coasts of the New World. Later, in Holland, they may have learned a good deal about the prosperous condition of the fisheries of Holland, especially those for herring. This may have fired them with the desire to proceed to the New World where reports stated that the sea adjacent to it "teemed with fish." For many years after the Pilgrims landed, the fisheries of New England continued to hold the attention of European nations, and other fishing colonies were established at strategic points.

To illustrate the importance that the nations of the Old World attached to the fisheries off the coast of the New World, it may be pointed out that according to Sabine (1852) the rivalry between the Dutch and English, each claiming exclusive right to the whale fisheries in the waters off the New World, terminated in a general war between these nations in 1618.

Salting Fish Operations on the Atlantic

In the early days of the colonial settlements along our New England coast, fishing was conducted only a few miles from shore, the catch usually being returned to port for processing. The fishing ships for the most part were none too seaworthy. However, since plenty of fish were to be found in the inshore waters, it was not necessary to utilize larger vessels. Later, as fish became more scarce along shore and the demand for them increased, larger vessels were built which were suitable for prosecuting the fisheries on the offshore banks. In order to return the fish caught by these larger vessels to port in good condition, it became necessary to salt the fish on board the vessel as was done formerly by the European fishermen frequenting these waters. Salting continued to be the principal method of preserving the catch on board the vessel until about the time of the Civil War. At that time it was demonstrated that fish could be packed in ice during the fishing voyage and could be landed in prime condition. As time went on, the fresh, iced fish met with a greater demand than the salted fish and as a result the landings of salted fish declined. In 1900, 55,000,000 pounds of salted fish and 107,000,000 pounds of fresh fish were landed at Boston and Gloucester (Fiedler, 1931) but in 1935 only 4,000,000 pounds of salted fish were

landed at these ports compared with 354,000,000 pounds of fresh fish (U. S. Bureau of Fisheries, 1936).

Operations on the Pacific

While our fishermen were conducting a salt cod fishery off the New England Coast, other United States fishermen were prosecuting a salt cod fishery in the North Pacific. The Pacific industry appears to have started in 1857 (Cobb, 1927) when Captain Matthew Turner, sailing from San Francisco, discovered cod at the mouth of the Amur River while his freighter, the "Timandra," lay at anchor in Castor Bay at the head of the Gulf of Tartary awaiting the breakup of ice in the river. During this delay his crew fished from the ship and caught considerable cod. On subsequent trips Captain Turner continued to notice the abundance of cod in these waters, and in 1863 decided to make a trip especially for salting cod, taking along salt and other provisions for this purpose. His expedition was a success and he returned to San Francisco with a cargo of salt cod which sold for fifteen cents a pound. This was the first time that salt cod taken on the fishing grounds in the Pacific were landed at a West Coast port.

Captain Turner's success encouraged others to engage in the Pacific cod fisheries. In 1864 a salt-cod vessel, the schooner "Alert," visited the Bering Sea. Little is known about this voyage except that it proved a failure.

Later Captain Turner searched for cod nearer our shores and in 1865 found them abundant around the Shumagin Islands along the Alaskan Peninsula. To this day a large part of the cod, salted on the Pacific by our vessels, is taken around these islands.

Icing and Freezing Fish

In an effort to land a better iced fish-product, studies were conducted by Sölling in 1905 (1910) on gutting the fish on board the vessel, wrapping the dressed product in vegetable parchment paper, and storing these packages in ice until port is reached. The experiments also were directed toward using the process for land shipments. While a modification of Sölling's method is used extensively at the fishing ports to pack fillets for inland transportation, little or no use has been made of it aboard vessel. However, it is understood that in 1935 a small production of fillets was packed in ice at sea and landed at Boston.

During late years some vessels have been equipped with mechanical refrigeration to aid in preserving at sea the original quality of the fish caught. In the beginning this equipment was used primarily to prevent the usual stock of ice carried by the vessel from melting so quickly. In more recent years it has been used to freeze the fish. From present indications it appears that the freezing of fish on board the vessel has promise of more general application.

The first mechanical refrigerating equipment on a United States vessel was installed in 1926 on the "Radio," a halibut fishing vessel (Pacific Fisherman, 1928). In this case it was used to retard the melting of the ice. The first practical refrigeration installed on a tuna vessel was completed in 1927, when Captain Guy Silva built an ammonia gas ice machine aboard his vessel, the "Louis S." (Chute, 1930). In 1930, Captain Silva increased his refrigeration capacity so that he could actually freeze the fish on board the vessel. It was stated that with this equipment Captain Silva could hold his vessel on the fishing grounds around the Galapagos Islands a month if necessary to obtain a catch, and in the meantime the fish already caught would remain in prime condition. The success of this venture has been an incentive to owners of other tuna clippers to install similar equipment.

During the period, 1927-29, the fishing industry on the Atlantic Coast gave considerable thought to using mechanical refrigeration on board vessels, either to freeze the fish or to keep the usual supply of ice from melting so rapidly. Some in the industry argued that it was not practical to install such equipment while others believed the refrigerated vessel would prove of value in maintaining the quality of the fish landed at port (Taylor, 1928; Kolbe, 1929). Prior to this discussion, however, some installations were made aboard fishing vessels operating from Atlantic ports. The first of such refrigeration equipment was installed on the "Princeton" in 1927 and was used in conjunction with ice. Kolbe stated (1929) that this saved one-half in the ice bill and that it is also possible to build a "factory ship" for putting up rapidly frozen fish. The installation on the "Princeton" was followed by one on the "Cormorant" in 1929 which also was used in conjunction with crushed ice.

During 1936 several new trawling vessels were launched in New England. In general, these are equipped with mechanical refrigeration systems which circulate cold air throughout the fish hold. They are operated in conjunction with crushed ice and are said to be capable of maintaining a temperature of around 32° F. or a few degrees above. Through the use of these systems it is expected that icing costs will be reduced greatly.

While our fishery industry has been proceeding with these refrigeration installations, members of the industry in Europe have been developing a true "factory ship" for freezing fish at sea. The French trawling vessel "Zazpiakbat," a barquentine of about 1,000 tons capacity, formerly engaged in the salt fishing trade, was equipped with freezing apparatus, and during its fishing operations on the Grand Banks in the spring, summer, and fall of 1929 the catch was frozen on board. (Fishing Gazette, 1929). Pellissier (1931) reported that the installation of freezing apparatus has become necessary because the demand for salt fish is decreasing in France and that for fresh fish is increasing.

Italy also became interested in freezing fish at sea about 1929, when refrigerating equipment was installed aboard the Italian trawler "Naiade." This vessel has a length of 136 feet, a capacity of fifty tons, and rooms for freezing and storing fish.

In August 1931, the French trawler-freezer, the "Jean Hamonet," paid a call at the port of Boston and was opened for inspection (Fishing 1931a). This vessel has the capacity to freeze about twenty tons of fish per day and to store approximately 140 tons of frozen fish. Her sister ship, the "Marie Helene," is also equipped to freeze fish. Both of these vessels were changed over from craft used in the salt fish trade on the Grand Banks. These trawlers, called "Frigorific" vessels by the "Fish Trades Gazette" of London, can be absent from port for thirty-five to forty days without refueling, during which time the fish can be kept in prime condition. Those who visited the "Jean Hamonet" at Boston were impressed with the cleanliness surrounding the freezing apparatus and of the vessel in general. One observer stated that the adoption of this system by American vessels might attract native Americans to fishing, since at the present time they are not inclined to enter the fisheries as a vocation. (Fishing, 1931b).

For a number of years the "Blue Peter," a mother ship equipped with freezing and cold storage facilities, has been operated off the coast of Newfoundland and Labrador (Zarotschenzeff, 1930). This is a vessel of 4,300 register tons with a storage capacity of 2,600 tons. It has been engaged primarily in freezing Atlantic salmon for marketing in England. The vessel, which follows the runs of salmon, is accompanied by a fleet of small vessels which collect the salmon from the fishermen and deliver the fish to the mother ship. It has not been possible for this refrigerated ship or its auxiliary vessels always to make quick contact with the fishermen. Thompson (1930) suggested that a floating cannery operated off Newfoundland during the salmon season might correct this situation by contacting those fishermen who cannot deliver their catch promptly to one of the bases for freezing.

Owners of vessels in Norway also have become interested in the freezing of fish at sea (Fishing Gazette, 1931). In 1931 the Norwegian factory ship, S. S. "Lesseps," was used for conducting experiments in quick freezing and cartoning at sea. The vessel at that time could produce one and one-half tons of cartoned frozen fish per day. It is understood this vessel is no longer in this business.

In later years other refrigerator ships have been operated from Norway. These have conducted operations off the coast of Greenland, and some in Davis Strait, where halibut were caught and frozen on board. Some conducted salt-cod operations in connection with the halibut-freezing business. In 1936 it is understood one of these vessels operated in connection with a Newfoundland whaling station, freezing the whale meat on board for marketing as a fox feed in Norway.

Two British factory ships also have engaged in the halibut-freezing

business off Greenland and in Davis Strait in recent years. It is understood that during the past year these were sold to Soviet Russia.

Recently Japanese vessels have been conducting experiments in freezing fish and shellfish aboard vessels. One of these, the "Mianto Maru," has operated in the Gulf of California (Pacific Fisherman, 1936c). During June 1936 it landed 134 tons of shrimp and sea bass at San Pedro, this being the second visit during the year. The shrimp were transshipped to the Orient and the sea bass were sold locally.

From time to time several motor vessels, operating in Alaska, have been equipped to freeze fishery products. One of these, the "Donna Lane," operated for several years in the halibut freezing trade. In 1930 she delivered about 600,000 pounds of frozen halibut at Seattle (Kastner, 1931). Later she was engaged in the business of salting herring for market and freezing them for bait. Other vessels of this type also operated in Alaska as floating salteries for herring or salmon (Pacific Fisherman, 1936 a and b).

Canning Fish

Let us now consider the factory ship engaged in canning fish. As far as I can determine, ships of this type are operated only on the Pacific Ocean by citizens of the United States and Japan. The United States vessels are concerned mainly with canning salmon, while those of Japan can salmon as well as the spider crab.

The United States vessels conduct their canning operations within the territorial waters of Alaska and are subject therefore to the regulations promulgated by the U. S. Department of Commerce. The vessels owned by Japan conduct their salmon and crab operations principally off the coast of Asia although some of the crab canning vessels operate in the international waters off Alaska in the vicinity of the Bering Sea. The vessels of both nations are equipped with modern canning machinery and quarters for both the crew and the personnel employed for canning.

According to Cobb (1931) the first floating salmon cannery to operate on our Pacific Coast was built in 1867 on a scow by S. W. Aldrich, a ship carpenter. This cannery operated only a year or two on the Columbia River. The next attempt seems to have been in British Columbia, where in 1883 Joseph Spratt started a floating salmon cannery on a vessel known as "Spratt's Ark."

The earliest canning of salmon aboard a vessel operated in Alaska, occurred in 1911 (Cobb, 1931). In that year the old clipper ship, "Glory of the Seas," was outfitted as a floating cannery and operated in southeast Alaska. This vessel was again operated in 1912 along with another floating salmon cannery built on board the "William H. Smith." Since 1912 the operations of floating salmon canning vessels by our fishermen have been rather intermittent. During the years 1930 to 1935 inclusive, from two to six American vessels operated each year, princi-

pally in waters of Alaska. A total of nine United States vessels have been equipped to can salmon during this period.

The Japanese have operated floating crab canneries since 1916. They operated off the coast of Asia where their principal activities still are centered. Since 1930 several of these factories have operated in international waters off the coast of Alaska, mainly off Bristol Bay (Bower, 1931 to 1935). These vessels are equipped with machinery for canning the meat of spider crabs. The crabs are caught in nets fished from small power launches. Usually the vessel carrying canning equipment is accompanied by a steam trawler which catches the so-called trash fish. Some of the Japanese mother ships operating off the coast of Alaska are equipped with machinery for manufacturing fish meal and oil from these trash fish.

In 1930 and in 1931 the Japanese operated one cannery vessel and one trawler in waters off Alaska; in 1932, one cannery vessel and two trawlers, together with one vessel which brought supplies and carried back part of the pack; in 1933, four cannery vessels and one trawler; in 1934, three cannery vessels and two trawlers; in 1935, two cannery vessels and three trawlers; in 1936, two cannery vessels and five trawlers. In all, about nineteen different cannery and trawling vessels from Japan conducted fishery operations off Alaska during these years. The only pack reported for a single vessel for one season was one of 33,000 cases, packed in 1932. Each case consisted of ninety-six one-half pound cans.

An idea of the size of the crab cannery vessels operated by Japan in the international waters off the coast of Alaska may be obtained from the measurements of the "Taikoku Maru," which is of 7,834 tons, has a length of 500 feet, and a beam of fifty-two feet. It carries 300 men who comprise the crew and the personnel employed in the cannery and fishery operations. In 1932 the "Nagato Maru," carried a crew of forty-five men and 400 others for work in the cannery, or for fishing. In 1934 the crab nets of one vessel covered an area of 350 square miles.

The crab meat packed by these Japanese vessels off the coast of Alaska and transported to Japan may ultimately reach the market in the United States. In 1934 the United States imported about 5,200,000 pounds of canned crab meat from Japan, while our domestic production of fresh-picked crab meat amounted to about 5,600,000 pounds.

Whale Reduction Into Meal and Oil

About 1715 (Jefferson, 1791) our New England fishermen took an interest in the whale fishery. At first it was conducted within a few miles from shore and the whales were brought to port for processing. Soon, however, whales were sought in more distant waters because of the great demand for whale oil and because the inshore grounds were becoming depleted. To navigate these waters larger vessels were built. These were capable of making longer voyages and were equipped with machinery on board to render the oil from the whales. Before the

Revolutionary War the whale fishery was conducted mainly out of Nantucket, an island which Thomas Jefferson stated might support about twenty families in agricultural pursuits. Because of the whale fishery, however, the island supported a much larger population, as this fishery alone gave employment here to about 6,000 men and boys.

Later the headquarters for the whale fishery moved to New Bedford and in 1840 this was the principal home port of the whaling fleet. About this time our whalemen were scouring the seven seas for whales to meet an ever growing demand for the oil. Some fished in the waters of the North Atlantic; others in the South Atlantic off the coasts of both Africa and South America. Some rounded the "Horn" to fish in the Antarctic and in the Pacific, off the coasts of both America and Asia, as far north as the Bering Sea. On voyages to this latter area some of the vessels were gone two or more years before they returned to their home port.

After the whaling fishery became firmly established in the Pacific (about 1840), American whaling vessels were sometimes wrecked off the coast of Japan. According to Hawks (1856) members of the crews of such vessels, who reached shore alive often were imprisoned and treated with "great cruelty and inhumanity." At that time, Japan had her ports closed to all nations except China and Holland, and even the vessels of these two nations were permitted to call at only one or two designated ports. No foreigner was supposed to set foot on the soil of Japan. Further, no Japanese were permitted to leave the islands, and those who did were not allowed to return (Hawks, 1856). In one instance a Japanese fishing vessel drifted eastward across the Pacific and landed on the Pacific Coast near the mouth of the Columbia River. The crew was returned to Japan by an American vessel but the members were denied entry.

During this period fishing was one of the principal industries of the Japanese, but the fishing craft were not allowed to venture far from shore (Hawks, 1856). In order to assure conformance with this regulation, another law required that all vessels built in Japan and manned by Japanese were to be constructed with an open stern. This, of course, made it virtually impossible for the fishing vessels to weather a heavy sea. Therefore, the range of fishing of the Japanese craft was within a few miles from shore. In spite of all these restrictions the inshore fleet was very large because of the great demand for fish in Japan (Hawks, 1856).

It is of interest to note that the harsh treatment accorded the crews of our shipwrecked whaling vessels by the Japanese had a direct bearing on Commodore Perry's expedition to Japan in the years 1852 to 1854 (Hawks, 1856). One of the great objectives of the expedition was to obtain friendly admission of our vessels to the ports of Japan for purposes of trade. Enroute to Japan, Commodore Perry elaborated on this point in a communication from Madeira, dated December 14, 1852, to

the Secretary of the Navy. He said that as a preliminary step to his objective he hoped to secure one or more ports of refuge and supply in Japan for our whaling and other ships. Reference again is made to this refuge for our whaling and other ships in a letter transmitted by Commodore Perry from the then President of the United States, Millard Fillmore, to the Emperor of Japan.

The outcome of Commodore Perry's expedition is, of course, well known. Japan entered into a treaty with the United States, containing, among other terms, provision for the entry of our whalemen to ports of Japan for supplies and refuge. The treaty also paved the way for Japan to enter world commerce and trade.

Unfortunately, soon after Commodore Perry made his visit to Japan our whale fishery declined, as did that of other nations, due to two circumstances: First, to the difficulty of obtaining a catch at a cost that would allow profitable competition with the newly discovered mineral oil which was used as an illuminant in place of whale oil; second, to the fact that the whale population in the sea was being depleted in those areas where the whaling fleet could operate successfully.

The activities of our whaling fleet, covering as it did many of the ports of the world, had a most favorable effect in enlarging our world trade and commerce. The prosecution of the fishery in the Pacific not only assisted in opening the ports of Japan to our trade but it no doubt was instrumental in bringing about the colonization of certain Pacific islands as well as some of our Pacific Coast areas by our people.

At the height of the fishery in the Pacific, considerable whale oil and whalebone was landed at Hawaiian ports for transshipment by sailing vessels around the "Horn" to Atlantic ports (Cobb, 1902). Also, many Pacific islands were discovered and settled by our whalemen. The descendants of some of these whale fishermen still inhabit some of these mid-Pacific islands. About the middle of the nineteenth century much oil was transshipped from San Francisco around the "Horn" by sailing vessels, and, later, after the building of the Transcontinental Railroad, a considerable amount of whale products was landed at the port of San Francisco and transshipped east over this railroad.

The exploits of our whalemen and fishermen in the Pacific off the coasts of Alaska had a bearing on the purchase of this territory from Russia. Our whalemen were well acquainted with the coasts of this territory and its harbors for safe refuge and supplies, for they pursued whales in the Gulf of Alaska and far into the Bering Sea. These fishery activities, therefore, were given considerable attention in the negotiations between the United States and Russia relative to the purchase of Alaska. Before the purchase, the ports of Alaska were officially closed to our fishing vessels; in fact, our vessels were not supposed to approach within one hundred miles of the coast of Alaska north of the fifty-first parallel. It was thought by some Russian authorities that this exclusion in due course might lead to serious con-

sequences, such as the closing of our Pacific ports to Russian trade (Larned, 1922).

The importance of the fisheries off Alaska to the United States also is indicated (Larned, 1922) by the fact that a memorial of the legislature of Washington Territory to the President, received in February, 1866, was made an occasion, in general terms, for communicating to the Russian Minister to the United States the importance of some early and comprehensive arrangement between the two countries to prevent the growth of difficulties arising out of the fisheries in Russian possession on the North American continent.

As is known, the United States in due course purchased Alaska from Russia. The formal transfer took place on October 18, 1867, at Sitka, Alaska. This marks the date of our development of the great fishery resources of this Territory.

In connection with the rise and decline of the whale fishery during the last century, it is of interest here to record the most recent developments in the fishery which give promise of elevating it again to one of world prominence. With the discovery of new uses for whale oil in the manufacture of soap, cold cream, and butter substitutes, and with a world shortage of oils and fats in general, the demand for whale oil recently has increased by leaps and bounds. This has led to a most intensive hunt for whales, especially in those waters of the world which formerly were not explored because the early whaling ships were not able to withstand the weather and ice conditions in these waters. Neither were these vessels as well equipped to render the oil from the whale as the present-day whaling ship. I refer to the great whale fishery now conducted in the Antarctic by huge factory ships of the most modern type. They are staunchly built to withstand most any type of weather and are equipped with the most modern machinery. Some can even haul the entire whale aboard the vessel for cutting up, whereas in the early whaling days part of the cutting up processes had to be done while the whale was in the water alongside the vessel. The modern factory ships, known as "mother ships," usually are accompanied by small steamers or "catcher boats." These small boats catch and deliver the whales to the mother ship for processing. In the Antarctic regions some processing is also done at shore reduction stations.

In the early years this newer type of whaling factory ship was a vessel which had been remodeled to make it suitable for the whale trade. In recent years, however, vessels have been built especially for the whaling business. In 1929 the "Kosmos," a Norwegian vessel designed and built especially as a floating factory ship for whale reduction, entered the fishery in the Antarctic (Industrial Chemist, 1929). The "Kosmos" has a displacement of about thirty-two thousand tons with the following dimensions: length 570 feet, breadth seventy-seven feet, and depth fifty feet six inches. It has on board the most modern

machinery for the cutting up and reduction process, as well as apparatus for distilling fresh water, refrigeration equipment for food, large storage tanks for the whale oil, accommodations for a crew of three hundred persons, and other modern conveniences. Since the launching of this ship, others of even larger size have entered the fishery, including the Norwegian vessel, the "Kosmos II", of thirty-four thousand tons. These vessels are able to remain at sea for long periods.

The profitable nature of the enterprise has resulted in great expansion of the whale fishery in recent years. The "Sir James Clark Ross," after concluding fishing operations in the Antarctic during the season of 1930-31 when 1,440 whales were taken, landed at New York City with 55,000 barrels of whale oil (2,750,000 gallons) with an estimated value of between $1,500,000 and $2,000,000 (New York Times, 1931). Dividends from some whaling companies operating in the Antarctic have ranged from ten to thirty per cent or more (Radcliffe, 1934).

The Antarctic fishery, which is by far the largest now, is carried on mainly by Norway and Great Britain. In addition, vessels from the United States, Argentina, Chile, Denmark, Iceland, Japan, Mexico, Portugal, (Azores) and U. S. S. R. also prosecute the whale fishery, some in the Antarctic and others at ports nearer home, but in the aggregate practically covering the world's seven seas. Our vessels operate off Alaska and California and one vessel operates off Australia.

According to a news item in the Washington Herald (Washington, D. C.) on November 15, 1936, the German whaling factory ship "Terje Viken" left for the Antarctic in early November. When fully laden this vessel has a displacement of 43,000 tons, making her the world's largest factory ship. The year 1936 marked the entrance of Germany into the whale fishery after a lapse of seventy-two years.

During the 1934-35 season the whaling vessels of all nations captured 39,254 whales, which produced 2,691,000 barrels of oil[1] (Committee for Whaling Statistics, 1936). Except for the season of 1930-31, this is the largest world production of whale oil on record and may possibly exceed the world production in even the most balmy days of the fishery in the nineteenth century, although to my knowledge no comparable records on the world production for the early days are available to corroborate this statement. Of the total 1934-35 production, the United States vessels produced only about twenty-five thousand barrels.

Lest history repeat itself, steps recently were taken toward conserving the whale fishery of the world. A Multilateral Convention for the Regulation of Whaling was signed by twenty-six nations interested in the catching or processing of whales or in the consumption of products derived from the whale. This became effective in January, 1935, and at the seventy-fourth Congress, Second Session, appropriate legislation to give effect to the Convention was enacted and was approved by the President on May 1, 1936.

[1] One barrel equals 1/6 ton; 1 ton equals 1,016 kilograms.

Pilchard Reduction Into Meal and Oil

The most recent type of factory ship to enter our fisheries is that devoted to the manufacture of meal and oil from the pilchard, otherwise known as the California sardine. The first of these ships began operations in 1930. They range from 1,224 gross tons to 6,065 gross tons. Beside the crew they carry the workers who operate the reduction machinery. These factory ships are supplied raw sardines by smaller craft which unload their catch directly on the factory ship at sea. Until 1934 these ships confined their operations in waters off California. By working outside the territorial waters of the State they avoided compliance with regulations of the State of California governing the sardine industry. In 1935 and 1936 operations were extended to Oregon and Washington, where sardines were available during the off season in California.

In 1935 five factory ships were in operation and, according to an article in the "Pacific Fisherman" (1936d) it is expected that eleven will be in operation in 1936. Since the entry of factory ships in the sardine industry, the total production of oil and meal has increased from 5,800,000 gallons of oil and about 26,000 tons of meal in 1930 to 21,700,000 gallons of oil and about 96,000 tons of meal in 1935.

Summary

From the foregoing it is evident that the factory ship has played an important rôle in developing our fisheries and promoting our trade and commerce. Practically every type of fish processing is now conducted on board these ships, which, being mobile units, can operate in almost any waters of the seven seas where supplies of raw fish or other aquatic products are obtainable. Just as the frontiers of the whale fishery were pushed farther and farther from the home port by the old factory ship, so the modern factory ship has extended our fishing areas for many species of fish. Now forty to fifty per cent of our fishery harvest is taken beyond our territorial waters.

The factory ship has enabled not only our fishermen to extend the range of their operations but also those of other nations. Consequently, the production of the sea fisheries has increased to such an extent as to have raised the question of the conservation of the fishes or other marine animals processed on board ship.

In the early days our whale fishery gave employment to thousands of men and boys who could not find employment elsewhere. Now again, with an increase in the number of our factory ships many workers are finding employment which they could not obtain elsewhere. It is not at all improbable that by the use of the factory ship many new fisheries will be discovered and developed, which in turn will employ many more thousands of people on vessels, or in shore occupations, thereby adding greatly to our national income.

On the other hand, many have given consideration to the question of the effect these factory ships may have on the abundance of some of the marine fishes or other animals. As mentioned previously, a Convention is in effect to conserve the whale fishery of the world. Also, a treaty is in effect between the United States and Canada (Great Britain) to conserve the Pacific halibut fishery. Should similar measures be taken to safeguard the supply and sustain production of other marine species taken in international waters and processed on the high seas by the factory ship? Any attempt to develop such measures should consider the operations of the factory ship from all angles. It should weigh the merits of the factory ships as a means for creating employment and wealth and providing food for the nation, against the effect that unregulated activities of these vessels may have in depleting the high-sea fisheries.

It is believed that within the next few years the number of factory ships operated by United States interests as well as by citizens of other countries, will be increased. Some of these may be outfitted to process aquatic products now processed entirely on shore. For these reasons, I have prepared this paper in the hope that it may be of some value to the Special Committee of the Society in developing a North American fish policy, and also to the Foreign Relations Committee of the Society.

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APPENDIX

AMERICAN FISHERIES SOCIETY
Organized 1870

Certificate of Incorporation

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certifying in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

Seymour Bower	(Seal)
Theodore Gill	(Seal)
William E. Meehan	(Seal)
Theodore S. Palmer	(Seal)
Bertrand H. Roberts	(Seal)
Hugh M. Smith	(Seal)
Richard Sylvester	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

OF THE

AMERICAN FISHERIES SOCIETY

(As amended Sept. 4, 1936)

ARTICLE I

NAME AND OBJECT

The name of this Society shall be American Fisheries Society.

The objects of this Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

ARTICLE II

MEMBERSHIP

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may, upon the payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privileges of active membership for the duration of his life.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be ($5.00) dollars per year.

Libraries.—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2.00) dollars per year.

State Memberships.—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State memberships shall be twenty ($20.00) dollars per year.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the Governors of the several states, and the Secretary of Commerce of the United States, the Governor-General of Canada, the Lieutenant-

Governors of the several Canadian provinces, and the Dominion Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

Election of Members between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

Rights and Duties of Members.—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notices, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues. Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of Transactions.

Quorum.—Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form

an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary. The Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings. A majority of the Executive Committee shall constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee, except the members of the Committee on Common and Scientific Names of Fishes.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

ARTICLE V

Standing Committees

The standing committees shall be Executive; Foreign Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by article IV.

The Committee on Foreign Relations shall be composed of seven members selected by the nominating committee for election, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fisheries biologists, conservation and fisheries administration officials, fish culturists, or acquicultural societies. A report based on such exchange should be presented at each regular meeting.

The Committee on Common and Scientific Names for Fishes shall be composed of seven members selected for election by the nominating committee. Its duties shall be to establish and maintain in the files of the Librarian of this Society a correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

ARTICLE VI

Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

ARTICLE VII

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
   a. President
   b. Secretary
   c. Treasurer
   d. Vice-Presidents of Divisions
   e. Standing Committees
   f. Special Committees
5. Committees appointed by the President:
   a. Committee of five on nomination of officers and standing committees for the ensuing year.
   b. Committee of five on time and place of next meeting.
   c. Committee of five on resolutions.
   d. Auditing committee of three.
   e. Committee of three on program.
   f. Committee of three on publicity.
   g. Committee of five on publications.
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

ARTICLE VIII

Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least twenty-five members are present at said regular meeting.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
Governor-General of Canada.
Lieutenant-Governors of the several Canadian Provinces.
Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Dr. Nicolas, c/o Zoological Laboratory, University of Southern California, Los Angeles, Calif.
'04 Denbigh, Lord, London, England.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof Superintendent of Fisheries, Lund, Sweden.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond & Goodwin, 485 California St., San Francisco, Calif.
'15 California Barrell Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore & Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The. W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.

'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware & Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S., Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wisconsin.
'25 Bradford, W. A., 14 Wall St., New York, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'11 Cleveland, W. B., Burton, Ohio.
'04 Coker, Dr. Robert E., University of North Carolina, Chapel Hill, N. C.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'10 Gardner, Mrs. Charles C., The Cliffs, Newport, R. I.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'23 Grey, Zane, Altadena, Calif.
'28 Hall, W. A. Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'23 Lloyd-Smith, Wilton, 63 Wall St., New York, N. Y.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco, Calif.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3d St., Columbus, Ohio.
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'04 Palmer, Dr. Theodore S., 1939 Biltmore St., N. W., Washington, D. C.
'08 Prince, Dr. E. E., Dominion Commissioner of Fisheries, Ottawa, Canada.
'10 Radcliffe, Lewis, 5600 32nd St., N. W., Washington, D. C.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina, S. A.
'22 Walcott, Frederic C., State Office Bldg., Hartford, Conn.
'98 Ward, Dr. Henry B., University of Illinois, Urbana, Ill.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

'16 Adams, Dr. Charles C., State Museum, University of the State of New York, Albany, N. Y.
'35 Adams, Harry E., U. S. Forest Service, Milwaukee, Wis.
'33 Adams, Milton P., 638 Sunset Lane, East Lansing, Mich.
'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
'31 Agersborg, Dr. H. P. K., National Park Service, Washington, D. C.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'33 Aitken, W. W., 1054 38th St., Des Moines, Iowa.
'33 Albert, W. E., Jr., Lansing, Iowa.
'31 Aldrich, A. D., 2879 East Archer, Tulsa, Okla.
'34 Alexander, George J., Parliament Bldgs., Victoria, B. C., Canada.
'35 Allen, George W., Stevens Point, Wis.
'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
'32 Allen, Dr. William S., P. O. Box 7, Sherbrooke, P. Q., Can.
'34 Allers, Charles J., Cheboygan, Mich.
'26 Alm, Dr. Gunnar, Commissioner of Fresh Water Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
'23 Amsler, Guy, 902 Wallace Bldg., Little Rock, Ark.
'33 Anderson, Albin, State Fish Hatchery, Glenwood, Minn.
'08 Anderson, August J., Box 704, Marquette, Mich.
'35 Anderson, Herman, Route 1, Iesaquah, Wash.
'33 Anderson, Wendell A., Woodruff, Wis.
'35 Anderson, William H., 13 Pine St., College Heights, Hyattsville, Md.
'35 Andrews, A. E., 405 State Library Bldg., Indianapolis, Ind.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
'14 Annin, Howard, Van Cortland Ave., Ossining, N. Y.
'29 Atkinson, C. J., Fisheries Dept., Ottawa, Ont., Canada.
'36 Atwood, Earl L., New Federal Bldg., St. Louis, Mo.
'34 Ault, Harold, Box 76, Fiatt, Ill.
'32 Baer, Harry D., c/o U. S. Bureau of Fisheries, Ennis, Mont.
'36 Bailey, Reeve M., University Museums, Ann Arbor, Mich.
'32 Bailliere, Lawrence, Stoutland, Mo.
'36 Baird, John C.
'32 Bajkov, Dr. A. D., Atlantic Biological Station, St. Andrews, N. B., Can.
'27 Baker, Clarence, 2 South Carroll St., Madison, Wis.
'36 Baker, Dr. Clinton L., c/o Southwestern, Memphis, Tenn.
'15 Balch, Howard K., 110 E. Seeboth St., Milwaukee, Wis.
'98 Ball, E. M., 107 Columbia St., East Falls Church, Va.
'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
'33 Bauman, Albert J., State Fish Farm No. 4, Russells Point, Ohio.
'34 Baur, S. P., Spirit Lake, Iowa.
'34 Baxter, Robert Gordon, 188 St. Denis Avenue, St. Lambert, P. Q., Canada.
'33 Beach, U. Sidney, Highland, Mich.
'34 Bean, L. L., Freeport, Maine.
'36 Beard, Daniel B., 72 Pondfield Rd. W., Bronxville, N. Y.
'34 Belknap, George W., P. O. Box 153, Magog, P. Q., Canada.
'34 Bell, Edward B., 84 Foster St., Lowell, Mass.
'33 Bell, Frank T., U. S. Bureau of Fisheries, Washington, D. C.
'18 Bellisle, J. A., Inspector General of Fisheries and Game, Quebec, Canada.
'36 Bennington, Neville, 1114 Bever St., Wooster, Ohio.
'13 Berg, George F., 1702 E. 12th St., Indianapolis, Ind.
'34 Bevan-Monks, K., 3 Prospect St., Westmount, P. Q., Canada.
'36 Biddle, Spencer, R. F. D. 1, Vancouver, Wash.
'36 Bielski, George J., State Fish Hatchery, Grayling, Mich.

'27 Birdseye, Clarence, General Seafoods Corporation, Gloucester, Mass.
'36 Bishop, Otto W., Alpena, Mich.
'34 Bishop, Sherman C., Dept. of Zoology, University of Rochester, Rochester, N. Y.
'24 Bitzer, Ralph, Montague, Mass.
'32 Blosz, John, Lake Park, Ga.
'36 Boesel, M. W., R. R. 2, Oxford, Ohio.
'32 Bogie, Robert R., 6740 Fourth Ave., Brooklyn, N. Y.
'35 Bost, Dr. J. E., Greer, S. C.
'33 Bottvill, George, Bottvill's Fish Hatchery, R. 2, Palmyra, Wis.
'34 Bouillion, E. A., Paspebiac, P. Q., Can.
'36 Bower, E. A., 986 Colfax Ave., Benton Harbor, Mich.
'00 Bower, Ward T., U. S. Bureau of Fisheries, Washington, D. C.
'36 Bowman, Harvey B., Clinton, N. Y.
'34 Bradley, Robert C., Burlington State Hatchery, Unionville, Conn.
'35 Bradt, G. W., Box 713, East Lansing, Mich.
'34 Brass, J. L., Hastings, Mich.
'20 Breder, C. M., Jr., New York Aquarium, New York, N. Y.
'34 Brown, Dr. C. J. D., Montana State College, Bozeman, Mont.
'30 Brown, James, Dept. of Conservation, Frankfort, Ky.
'34 Brown, Louis P., Insurance Bldg., Glens Falls, N. Y.
'32 Brown, Merrill W., Division of Fish and Game, 303 State Office Building, Sacramento, Calif.
'20 Buller, C. R., Pleasant Mount, Wayne County, Pa.
'34 Burhans, Charles, Warrensburg, N. Y.
'35 Burleson, Clyde, Cherokee, Okla.
'30 Butler, George Edward, Gull Harbour Hatchery, Hecla, Man., Canada.
'27 Byers, A. F., 5606 Queen Mary Rd., Montreal, Que., Canada.
'27 Cable, Louella E., U. S. Bureau of Fisheries, Washington, D. C.
'34 Cadwell, Graham, Anaconda, Mont.
'36 Cahalane, Victor H., National Park Service, Washington, D. C.
'36 Cahn, Dr. A. R., 610 Arnstein Bldg., Knoxville, Tenn.
'35 Carbine, William F., Institute for Fisheries Research, Ann Arbor, Mich.
'33 Carson, A. G., Green Bay, Wis.
'34 Cass, G. G., Gaspé, P. Q., Canada.
'35 Cassell, John David, Forest Service, Lone Pine, Calif.
'34 Catellier, J. N., Padoussac, Comte Saguenay, P. Q., Canada.
'23 Catt, James, District Inspector of Hatcheries, Customs House, St. John, N. B., Canada.
'34 Champlin, C. D., Rheims, N. Y.
'29 Chute, Walter H., Director, John G. Shedd Aquarium, Grant Park, Chicago, Ill.
'32 Clark, Arthur L., State Capitol, Hartford, Conn.
'33 Clark, G. H., Natural History Museum, Stanford University, Calif.
'35 Clark, J. E., Tamarack, Idaho.
'36 Clark, O. H., 217 Observation St., Ann Arbor, Mich.
'33 Clausen, Ralph G., N. Y. State College of Teachers, Albany, N. Y.
'21 Clemens, Dr. Wilbert A., Pacific Biological Station, Nanaimo, B. C., Canada.
'00 Cobb, Eben W., R. F. D., Farmington, Conn.
'34 Cobb, Kenneth E., Windsor Locks, Conn.
'35 Cogart, Clarence E., Dexter, New Mexico.
'34 Cohen, Arthur, Dept. of Zoology, McGill University, Montreal, Canada.
'35 Collier, Albert, Rockport, Texas.
'35 Conner, J. T., Box 357, Springfield, Tenn.
'28 Cook, A. B., Jr., Field Supt. of Hatcheries, Ionia, Mich.
'35 Cook, Blendon H., U. S. Fisheries Station, Laketown, Utah.
'34 Cook, Frank, Game and Fish Com., Cheyenne, Wyo.

'17 Cook, Ward A., U. S. Bureau of Fisheries, Duluth, Minn.
'33 Cooper, Gerald P., Univ. of Maine, Orono, Maine.
'34 Cooper, R. B., Strawberry Point, Iowa.
'33 Corcoran, John P., Pioneer Point Farm, Centreville, Md.
'32 Corder, H. G., Anderson Lake Hatchery, Kildonan P. O., Vancouver Island, B. C., Canada.
'34 Cote, P. E., New Carlisle, P. Q., Canada.
'32 Cowden, Sumner M., Conservation Dept., Albany, N. Y.
'13 Crandall, A. J., Ashaway Line & Twine Mfg. Co., Ashaway, R. I.
'33 Croker, Richard, State Fisheries Laboratory, Terminal Island, Calif.
'28 Crosby, Col. W. W., Box 685, Coronado, Calif.
'08 Culler, C. F., U. S. Bureau of Fisheries, La Crosse, Wis.
'28 Cumings, Ed., c/o Cumings Brothers, 901 S. Saginaw St., Flint, Mich.
'36 Curran, H. Wesley, 2912 S. Salina St., Syracuse, N. Y.
'34 Curtis, Brian C., Box M, Carmel, Calif.
'34 Davis, Charles T., Gaspe, P. Q., Canada.
'34 Davis, George William, 377 Orange St., Albany, N. Y.
'36 Davis, Henry P., Investment Bldg., Washington, D. C.
'23 Davis, Dr. H. S., U. S. Bureau of Fisheries, Washington, D. C.
'26 Day, Harry V., 510 Park Ave., New York, N. Y.
'35 Day, L. A., Colonial Bldg., Petermaritzburg, Natal, South Africa.
'31 Deake, Standish, Div. Fish and Game, 20 Somerset St., Boston, Mass.
'33 Deason, H. J., U. S. Bureau of Fisheries, University Museum Bldg., Ann Arbor, Mich.
'34 deAzevedo, Dr. Pedro, Rua Alexandrino Cavalcanti No. 137, Campina Grande, Parahyba, Brazil, South America.
'27 DeBoer, Marston J., Dept. of Conservation, Lansing, Mich.
'25 De Cozen, Alfred, 1226 Broad St., Newark, N. J.
'28 De Forest, Byron, P. O. 971, Great Falls, Mont.
'30 Deibler, O. M., Commissioner of Fisheries, Board of Fish Commissioners, Harrisburg, Pa.
'24 Dence, Wilford A., New York State College of Forestry, Syracuse, N. Y.
'19 Denmead, Talbott, 2830 St. Paul St., Baltimore, Md.
'23 Dennig, Louis E., 3817 Choteau Ave., St. Louis, Mo.
'33 Deuel, Charles R., State Fish Hatchery, Gloversville, N. Y.
'30 Devlin, Marie Blanche, Parliament Bldgs., Colonization Dept., Quebec, Can.
'99 Dinsmore, A. H., U. S. Bureau of Fisheries, St. Johnsbury, Vt.
'34 Doby, William A., 118 V St., N. E., Washington, D. C.
'32 Domogalla, Dr. Bernhard, 803 State St., Madison, Wis.
'34 Donaldson, Lauren R., Dept. of Fisheries, University of Washington, Seattle, Wash.
'34 Dorr, Thomas H., Boothbay Harbor, Maine.
'35 Doudoroff, Peter, Scripps Institute of Oceanography, LaJolla, Calif.
'36 Douglass, Edward J., Bureau of Fisheries, Northville, Mich.
'35 Downing, A. C., Route 5, Box 412, Akron, Ohio.
'36 Duddy, Thomas, Cambridge, N. Y.
'28 Dunlop, Henry A., International Fisheries Com., University of Washington, Seattle, Wash.
'24 Earle, Swepson, U. S. Bureau of Fisheries, Washington, D. C.
'32 Eaton, R. H., Pitt Lake Hatchery, Alvin, B. C., Canada.
'34 Eden, Berton E., Gaspe, P. Q., Canada.
'32 Ekers, L. A., 990 Notre Dame St., W., Montreal, Canada.
'34 Elkins, Winston A., U. S. Forest Service, Park Falls, Wis.
'34 Ellis, Dr. M. M., 101 Willis Ave., Columbia, Mo.
'33 Ellsworth, Robert E., Silver Creek Trout Station, East Tawas, Mich.
'13 Embody, Dr. George C., Triphammer Road, Ithaca, N. Y.
'35 Engelhardt, Fred W. A., U. S. Fisheries Station, Crawford, Neb.

'36 English, Dr. P. F., Connecticut State College, Storrs, Conn.
'35 Erekson, Z. Y., Mantua, Utah.
'34 Erkkila, Leo, Natural History Museum, Stanford, Calif.
'32 Eschmeyer, R. William, University Museums, Ann Arbor, Mich.
'35 Evans, George M., Skamania, Wash.
'04 Everman, J. W., Supervisor of Public Utilities, Dallas, Texas.
'35 Evins, Donald, Box 1515, Westwood, Calif.
'35 Ewers, Dr. Lela A., Cottey College, Nevada, Mo.
'34 Faigenbaum, Harold M., 1 St. Pauls Pl., Troy, N. Y.
'28 Fearnow, Theodore C., Berkeley Springs, W. Va.
'32 Fellers, Dr. Carl R., Massachusetts State College, Amherst, Mass.
'30 Fentress, Eddie W., U. S. Fisheries, Cortland, N. Y.
'32 Fiedler, R. H., U. S. Bureau of Fisheries, Washington, D. C.
'35 Fink, Carl, Deer Creek Lodge, Mineral, California.
'31 Fish, Dr. Frederic F., U. S. Fisheries Laboratory, 2725 Montlake Blvd., Seattle, Wash.
'33 Fisk, Harry T., Crown Point, N. Y.
'36 Flores, Francisco G., 2205 E. Howe St., Seattle, Wash.
'28 Foerster, Dr. R. Earle, Pacific Biological Station, Nanaimo, B. C., Canada.
'04 Follett, Richard E., 2134 Dime Bank Bldg., Detroit, Mich.
'36 Fontaine, Pierre A., 1604 Young St., Dallas, Texas.
'36 Foresman, B. L., 1085 Argyle St., Pontiac, Mich.
'35 Fortney, Robert, State Fish Hatchery, Paris, Mich.
'35 Foster, C. R., P. O. Box 14, American Falls, Idaho.
'10 Foster, Frederick J., 2725 Montlake Blvd., Seattle, Wash.
'24 Frantz, Horace G., Frantzhurst Rainbow Trout Co., Salida, Colo.
'22 Fraser, Dr. C. McLean, University of British Columbia, Vancouver, B. C., Canada.
'18 Fridenberg, Robert, 22 West 56th St., New York City, N. Y.
'36 Friedrich, George W., 1502 7th Ave., S. E., St. Cloud, Minn.
'35 Fruchter, W., Cortland Experimental Hatchery, Cortland, N. Y.
'36 Fry, F. E. J., University of Toronto, Toronto, Can.
'35 Fuqua, Charles L., U. S. Fisheries Station, Spearfish, S. Dak.
'34 Furrow, Dr. Charles A., 204 Atlas Life Bldg., Tulsa, Okla.
'28 Gage, Simon H., Stimson Hall, Ithaca, N. Y.
'34 Gagnon, Georges, 6265 St. Denis St., Montreal, Canada.
'34 Gagnon, L Philippe, Laurentides National Park Service, Parliament Bldgs., Quebec, Canada.
'24 Gale, R. G., State Fish Hatchery, French River, Minn.
'18 Garnsey, Leigh, Box 653, Redlands, Calif.
'36 Garrett, C. Clyde, 639 Merchants Exchange Bldg., San Francisco, Calif.
'34 Gauthier, Roger, 5141 Boulevard LaSalle, Verdun, P. Q., Canada.
'35 Gerken, C .O'Brien, W. G. O'Brien & Son, Barberton, Ohio.
'30 Gibaut, F. M., Dept. of Colonization, Game and Fisheries, Quebec, Can.
'26 Gibbs, George, Pennsylvania Station, New York, N. Y.
'35 Gibbs, John T., Conservation Dept., Albany, N. Y.
'36 Gillingham, Weston K., Bay Port, Mich.
'34 Girard, Rupert, Belle Anse, P. Q., Canada.
'35 Goldie, Dr. William, 86 College St., Toronto, Canada.
'27 Gordon, Seth, Bd. of Game Commissioners, Harrisburg, Pa.
'33 Goswell, John C., St. Peters, N. S. Can.
'31 Gowanloch, Dr. James Nelson, Chief Biologist, Bureau of Research, Dept. of Conservation, New Orleans, La.
'34 Graham, W. B., 54 Sunset Boulevard, Ottawa, Canada.
'28 Grammes, J. Frank, Grammes Brook Trout Hatchery, 1119 Linden St., Allentown, Pa.
'36 Gray, Donald V., East Tawa, Mich.

'26 Greeley, Dr. John R., Conservation Dept., Albany, N. Y.
'29 Greene, Dr. C. Willard, N. Y. State Conservation Dept., Albany, N. Y.
'34 Griffiths, Francis P., R. F. D., Richmond Ave., Berwyn, Md.
'31 Grim, D. N., Glen Eyre, Pa.
'13 Guerin, Theophile, Lock Drawer 590, Woonsocket, R. I.
'34 Hachey, H. B., Atlantic Biological Station, St. Andrews, N. B., Canada.
'35 Haemmler, Wilbur, Flatbrook Club, Bevans, N. J.
'28 Hale, Robert F., Malone, N. Y.
'26 Halferty, G. P., 600 Coleman Bldg., Seattle, Wash.
'35 Hall, Mark A., 2½ Finch Street, Rochester, N. Y.
'36 Hansen, Donald F., 219 Natural History Bldg., Urbana, Ill.
'10 Hansen, Ferdinand, Romanoff Caviar Co., Grand Central Palace, 480 Lexington Ave., New York, N. Y.
'35 Hanson, A. C., State Office Bldg., St. Paul, Minn.
'25 Hanson, Henry, State Fish Hatchery, Lanesboro, Minn.
'28 Harkness, Dr. William J. K., Dept. of Biology, University of Toronto, Toronto, Canada.
'35 Harper, D. C., State Fish Hatchery, P. O. Box 83, Cisco, Tex.
'17 Harriman, W. A., 39 Broadway, New York, N. Y.
'34 Haskell David C., Gansevoort, N. Y.
'33 Hawes, Harry B., Transportation Bldg., Washington, D. C.
'04 Hayford, Charles O., State Fish Hatchery, Hackettstown, N. J.
'34 Hayford, Robert A., Hackettstown, N. J.
'34 Hayter, L. W., 1503, Dorchester St., W., Montreal, P. Q., Canada.
'35 Hazard, T. P., Peace Dale, R. I.
'28 Hazzard, A. S., 1306 Wells St., Ann Arbor, Mich.
'36 Heiliger, Dudley B., U. S. Fisheries Station, Northville, Mich.
'08 Hemingway, E. D., 239 Elbow Lane, Philadelphia, Pa.
'33 Herndon, G. B., 724 Mulberry St., Jefferson City, Mo.
'32 Herrington, William C., Bureau of Fisheries, Biological Institute, Cambridge, Mass.
'23 Hesen, Herman O., Jr., U. S. Fisheries Station, Louisville, Ky.
'34 Hessler, William F., 80 Washington St., Reading, Mass.
'33 Hewitt, Edward R., 127 East 21st St., New York, N. Y.
'35 Hickey, LeRoy W., Route 1, Box 764, Astoria, Oregon.
'32 Higgins, Elmer, U. S. Bureau of Fisheries, Washington, D. C.
'35 Higgs, A., Qualicum Beach, B. C., Canada.
'15 Hildebrand, Dr. Samuel F., U. S. Bureau of Fisheries, Washington, D. C.
'32 Hile, Dr. Ralph, U. S. Bureau of Fisheries, University Museums, Ann Arbor, Mich.
'36 Hill, R. R., U. S. Forest Service, Federal Bldg., Milwaukee, Wis.
'33 Hills, Clifford, State Fish Hatchery, Wild Rose, Wis.
'08 Hinrichs, Henry, 853 W. Burchett St., Glendale, Calif.
'33 Hodgins, Capt. N. M., Qualicum Beach, Vancouver Island, B. C., Canada.
'35 Hoffmaster, P. J., Director, Dept. of Conservation, Lansing, Mich.
'23 Hogan, Joseph R., State Fisheries, Lonoke, Ark.
'36 Holloway, Ancil D., U. S. Forest Service, Cleveland, Tenn.
'34 Honey, Clarence W., Alpine Inn, Ste. Marguerites, P. Q., Canada.
'34 Honeyman, A. J. M., McGill University, Montreal, Canada.
'20 Hoofnagle, G. W., U. S. Fishery Station, White Sulphur, W. Va.
'36 Hoover, Earl E., 22A Fayette, Concord, N. H.
'24 Horst, Louis, Sunderland, Mass.
'33 Hosley, N. W., Harvard Forest, Petersham, Mass.
'35 Hosselkus, B. C., Creede, Colo.
'31 Howley, Thomas, 2482 Tiebout Ave., New York, N. Y.
'23 Hubbard, Harry E., New Hampton, N. H.
'00 Hubbard, Waldo F., U. S. Bureau of Fisheries, Hudson, N. H.

'20 Hubbs, Dr. Carl L., Univ. of Michigan, Ann Arbor, Mich.
'24 Huderle, John, State Fish Hatchery, Detroit Lakes, Minn.
'28 Hunter, George W., 3d, Shanklin Laboratory of Biology, Wesleyan University, Middletown, Conn.
'35 Hunter, Dr. R. P., Fish and Game Service, Montpelier, Vt.
'13 Huntsman, Dr. A. G., University of Toronto, Toronto, Canada.
'35 Hutton, M. L., Ames, Iowa.
'32 Jackson, Charles E., Deputy Comr., U. S. Bureau of Fisheries, Wash., D. C.
'32 James, C. C., Superintendent of State Fish Hatcheries, Summerville, Ga.
'33 James, Herman, c/o State Fish Hatchery, Summerville, Ga.
'28 James, Milton C., U. S. Bureau of Fisheries, Washington, D. C.
'17 Jensen, Harold, State Fish Hatchery, St. Peter, Minn.
'28 Jewell, Minna E., Dept. of Zoology, Thornton Junior College, Harvey, Ill.
'32 Jobes, Frank W., U. S. Bureau of Fisheries, Washington, D. C.
'34 Johnson, Edwin L., 14 Forest Ave., St. Thomas, P. Q., Canada.
'36 Johnson, Fred F., 5521 Colorado Ave., N. W., Washington, D. C.
'34 Johnson, Fred W., Box 278, Mt. Shasta City, Calif.
'35 Johnson, Harlan E., U. S. Fisheries Station, Spearfish, S. Da.
'35 Johnson, Harry, Verdi, Nevada.
'33 Johnson, Jimmie, c/o Game and Fish Dept., Santa Fe, New Mexico.
'25 Johnson, Maynard S., 44 Summer St., Saugus, Mass.
'35 Johnson, Rudolph E., R. 1, Arlington, Wash.
'34 Johnston, Herbert C., 134 Notre Dame Ave., St. Lambert, P. Q., Canada.
'35 Johnston, H. F., U. S. Fisheries Station, Bozeman, Mont.
'34 Johnston, Roy, Camp 95-S, Roscommon, Mich.
'36 Jones, Alton, Porters Lake Hunting and Fishing Club, Porters Lake, Pa. (via Marshall Creek P. O.)
'29 Jones, Dr. Jabez, De Renne Apartments, Savannah, Ga.
'36 Jones, M. L., 356 Washington St., Benton Harbor, Mich.
'08 Jones, Thos. S., 1664 Spring Drive, Louisville, Ky.
'32 Jordon, Morrison, South Esk, N. B., Canada.
'18 Kauffman, R. M., "The Star," Washington, D. C.
'26 Kaul, William, Saint Marys, Pa.
'99 Keil, W. M., 62 Maney Ave., Asheville, N. C.
'28 Kemmerich, Alphonse, U. S. Bureau of Fisheries, Underwood, Wash.
'12 Kemmerich, Joseph, U. S. Bureau of Fisheries, Birdsview, Wash.
'02 Kendall, Dr. William C., P. O. Box 171, Freeport, Me.
'28 Kenell, Garfield, Hamilton Lake Lodge, Lake Pleasant, N. Y.
'32 Kenney, Raymond J., 96 Cross St., Belmont, Mass.
'04 Kent, Edwin C., 80 William St., New York, N. Y.
'35 Kibbe, T. S., U. S. Fisheries Station, Clacksmas, Oregon.
'34 King, Charles L., Sabula, Iowa.
'32 Kingsbury, Oliver R., South Otselic, N. Y.
'24 Kitson, James A., 20 Somerset St., Boston, Mass.
'35 Knutsen, Arthur I., 3306 W. 70th St., Seattle, Wash.
'34 Koster, William J., 119 Eddy St., Ithaca, N. Y.
'32 Kuehl, Eric O., U. S. Fisheries Station, Springville, Utah.
'33 Kunkel, Kenneth M., Fish & Game Div., State House, Indianapolis, Ind.
'36 Kuronuma, Katsuzo, University Museum, Ann Arbor, Mich.
'34 Ladner, Grover C., 1501 Walnut St., Philadelphia, Pa.
'25 Langlois, Dr. T. H., P. O. Box C, Put-in-Bay, Ohio.
'29 Larsen, Henry A., Hayward, Wis.
'29 Lau, H. C., Star Prairie Trout Hatcheries, Star Prairie, Wis.
'34 Lauffer, Walter M., Mt. Gilead, Ohio.
'08 Lay, Charles E., Railroad St. Foot of Wayne St., Sandusky, Ohio.
'98 Leach, G. C., U. S. Bureau of Fisheries, Washington, D. C.
'19 LeCompte, E. Lee, 512 Munsey Bldg., Baltimore, Md.

'35 Legerwood, Ralph, Mt. Shasta, Calif.
'28 Leighton, F. W., Sonora, Calif.
'25 Leim, Dr. A. H., Atlantic Biological Station, St. Andrews, N. B., Canada.
'35 Leitritz, Earl, Fall Creek Hatchery, Copco, Calif.
'34 Lemay, Lionel, Universite de Montreal, Rue St. Denis, Montreal, Canada.
'34 LeMesurier, John P., Grand Greve, P. Q., Canada.
'34 Leonard, Justin W., Institute for Fisheries Research, Ann Arbor, Mich.
'34 Lewis, J. C., Tahoe City, Calif.
'35 Lewis, R. C., Hot Creek Rearing Ponds, Bishop, Calif.
'31 Liebig, Elmer R., Lakeside Hatchery, Redfield, S. D.
'27 Lilly, Eugene, The Lilly Ponds, 14 Alsace Way, Colorado Springs, Colo.
'30 Lincoln, Guy, State Fish Hatchery, Oden, Mich.
'36 Lindgren, Burt O., U. S. Bureau of Fisheries, Washington, D. C.
'32 Lindner, Milton J., 117 New Orleans Court Bldg., New Orleans, La.
'20 Lindsay, R. Charles, Gaspe, P. Q., Canada.
'34 Littlefield, J. E., 200 South Main St., Brewer, Maine.
'36 Littmar, Herman, Oden, Mich.
'22 Locke, Samuel B., 222 North Bank Drive, Chicago, Ill.
'32 Long, Louis J., Marlinton, W. Va.
'33 Looff, A. T., c/o U. S. Bureau of Fisheries Station, Quinault, Wash.
'27 Lord, Russell F., Pittsford, Vt.
'31 Loutit, Hon. W. H., Chairman, Conservation Commission, Lansing, Mich.
'32 Lucas, Clarence R., U. S. Bureau of Fisheries, Kodiak, Alaska.
'35 Lundgren, A. H., Quinault, Wash.
'33 Lydell, Claud, State Fish Hatchery, Hastings, Mich.
'34 Lyon, Harold P., 4102 Hingston St., Montreal, Canada.
'35 McCafferty, Thomas, Spring Grove, Ill.
'27 McCay, C. M., Animal Husbandry Dept., Cornell Univ., Ithaca, N. Y.
'36 McClanahan, D. H., State Game and Fish Dept., Oklahoma City, Okla.
'34 McDonald, C. M., 500 Trombley Rd., Grosse Point, Mich.
'29 McDowell, Robert H., Crawford, Neb.
'30 M'Gonigle, Dr. R. H., Atlantic Biological Station, St. Andrews, N. B., Canada.
'30 McKenzie, R. A., Biological Board of Canada, University of Toronto, Toronto, Canada.
'20 McKinney, Robert E., 16 Rosecliff St., Roslindale, Mass.
'31 McMurtrey, M. S., El Reno, Okla.
'35 McMahon, George P., State Fish Hatchery, R. R. 1, Pecatonica, Ill.
'34 McNamara, Fred, Howell, Mich.
'27 MacDonald, Kenneth F., Dept. of Fish and Game, Helena, Mont.
'26 Mackay, H. H., East Block, Parliament Bldg., E. 137, Toronto, P. Q., Can.
'35 Maclay, David J., Lo Lo, Mont.
'36 Madsen, David H., 803 Continental Bank Bldg., Salt Lake City, Utah.
'32 Magee Dr. M. D'Arcy, 5038 Reno Road, N. W., Washington, D. C.
'36 Makepeace, J. C., Wareham, Mass.
'31 Manning, Arthur, State Fish Hatchery, Medicine Park, Okla.
'36 Manning, Dr. J. R., U. S. Bureau of Fisheries, Washington, D. C.
'11 Marine, Dr. David, Montefiore Home & Hospital, Gun Hill Road, East 210th St., New York, N. Y.
'33 Marks, Jay G., State Fish Hatchery, Mattawan, Mich.
'33 Marks, Ralph S., State Fish Hatchery, Watersmeet, Mich.
'30 Markus, Henry C., Municipal Museum, Edgerton Park, Rochester, N. Y.
'25 Matsunaga, K., North Branch, N. J.
'21 Matthews, J. H., Ex-Sec. Middle Atlantic Fisheries Assn., 203 Front St., New York, N. Y.
'35 Mattingly, E. H., Jamestown, N. Da.
'28 Meehean, O. Lloyd, U. S. Fisheries Station, Marion, La.

'24 Mercier, Honoré, Paraliament Bldgs., Dept. of Lands and Forests, Quebec, Canada.
'26 Meredith, C. J., Bowling Green, Ky.
'30 Merritt, J. M., State Fisheries, Gretna, Neb.
'13 Mershon, W. B., Saginaw, Mich.
'35 Meyer, Marcus W., U. S. Bureau of Fisheries, Redding, Calif.
'20 Miles, Lee, 902 Wallace Bldg., Little Rock, Ark.
'33 Millar, Eric A., P. O. Box 490, Montreal, Canada.
'35 Millen, Bert, State Fish Hatchery, Put-in-Bay, Ohio.
'17 Miller, Albert P., Bemus Point, N. Y.
'35 Miller, C. R., Centralio, Ill.
'36 Miller, Donald E., Ball States Teachers College, Muncie, Ind.
'32 Miller, Ralph W., Accident, Md.
'34 Miller, Rupert A., Gaspe, P. Q., Canada.
'34 Milot, George, St. Alexis des Monts, P. Q., Canada.
'27 Mitchell, Dr. James F., P. O. Box 15, LaOroyo, Peru, South America.
'24 Mix, Oliver, State Fish Hatchery, St. Paul, Minn.
'20 Money Gen. Noel, Qualicum Beach, B. C., Canada.
'34 Monroe, William F., State Fish Hatchery, Palmer, Mass.
'32 Montgomery, George N., East Orland, Me.
'31 Moody, Ervin, R. F. D. 1, Mattawan, Mich.
'18 Mooré, Dr. Emmeline, Conservation Commission, Albany, N. Y.
'26 Moore, Frederic P., Locust Valley, L. I., N. Y.
'26 Morgan, Henry, East Islip, N. Y.
'34 Morisset, Paul 56 des Erables, Quebec, Canada.
'34 Morofsky, Walter F., Box 771, East Lansing, Mich.
'10 Moser, Rear Admiral Jefferson F., 2040 Santa Clara Avé., Alameda, Calif.
'25 Moss, William C., Crystal Spring Trout Hatchery, Port Allegany, Pa.
'20 Motherwell, Major J. A., Dept. of Marine and Fisheries, Rogers Bldg., Vancouver, B. C., Canada.
'34 Mottley, C. McC., Pacific Biological Station, Nanaimo, B. C., Canada.
'34 Mundt, Karl T., Madison, S. D.
'25 Murphree, J. M., State Fish Hatchery, P. O. Box 549, Durant, Okla.
'36 Myers, Dr. George S., Natural History Museum, Stanford University, Calif.
'30 Nachman, Fred, Park Rapids, Minn.
'18 Needham, Prof. James G., Cornell University, Ithaca, N. Y.
'28 Needham, Dr. Paul R., Stanford University, Palo Alto, Calif.
'32 Nelson, Thomas F., Fisheries Station, Dexter, New Mexico.
'33 Nesbit, Robert A., U. S. Bureau of Fisheries, Cambridge, Mass.
'34 Newcomb, Dr. W. E., 1532 Keith Bldg., Cleveland, Ohio.
'34 Nichols, Kenneth B., Warrensburg, N. Y.
'28 Norton, Raymond G., Bemus Point, N. Y.
'13 Oakes, William H., 24 Union Park St., Boston, Mass.
'34 Odell, Ralph W., 53 N. Main St., Franklinville, N. Y.
'29 Odell, Theodore, Hobart College, Geneva, N. Y.
'36 Olson, Herman F., U. S. Forest Service, Federal Bldg., Duluth, Minn.
'28 Olson, Theodore A., Minn. Dept. of Health, Div. of Sanitation, Univ. of Minn. Campus, Minneapolis, Minn.
'28 ONeal, Lloyd A., U. S. Fisheries Station, Northville, Mich.
'36 Osgood, Wayland, Dept. of Conservation, Lansing, Mich.
'35 Palmer, George, Lewistown, Md.
'34 Palmer, Robert C., Gaspe, P. Q., Canada.
'34 Parnell, Ivan W., Institute of Parasitology, Macdonald College P. O., P. Q., Canada.
'34 Patterson, Coleman S., Gaspe, P. Q., Canada.
'36 Patterson, Matt, 329 North Cedar St., Sturgeon Bay, Wis.

'35 Pautzke, Clarence F., Dept. of Game, Lloyd Bldg., Seattle, Wash.
'32 Pells, Frank, Cultus Lake Hatchery, Vedder Crossing, B. C., Canada.
'28 Pelnar, John, U. S. Bureau of Fisheries Station, Parkway, Wash.
'32 Peterson, Hans L., State Fish Hatchery, Grayling, Mich.
'33 Pettit, P. S., Watrous, Sask, Canada.
'30 Phillips, Dr. Alfred N., Middlesex Rd., Glenbrook, Conn.
'31 Phillips, Elmer, Fish and Game Dept., Helena, Mont.
'29 Phillips, G. C., State Fish Hatchery, Randolph, N. Y.
'34 Phillips, Mrs. J. T., Dept. of Zoology, McGill University, Montreal, Can.
'36 Pierce, Henry A., 606 Kalamazoo National Bank Bldg., Kalamazoo, Mich.
'36 Pirnie, Dr. Miles D., Kellogg Bird Sanctuary, Battle Creek, Mich.
'36 Platts, W. Carter, c/o Fishing Gazette, London, Eng.
'13 Poole, Gardner, 3 Commercial St., Boston, Mass.
'35 Porter, F. H., Triple Artesian Well Fish Hatchery, Bingham, Neb.
'35 Potter, M. E., University of Kentucky, Lexington, Ky.
'36 Potts, Lloyd W., Harrisville, Mich.
'25 Powell, Albert M., Lewiston, Md.
'33 Prevost, Gustave, McGill, University, Montreal, Canada.
'31 Pritchard, Dr. A. L., Pacific Biological Station, Nanaimo, B. C., Canada.
'32 Prytherch, Dr. Herbert F., U. S. Fisheries Biological Station, Beaufort, N. C.
'34 Pulis, Milton G., Oakland Trout Ponds, Oakland, N. J.
'35 Pollum, Lloyd T., U. S. Fisheries Station, Saratoga, Wyom.
'33 Purdy, N. H., Uhrichsville, Ohio.
'29 Quinn, I. T., Dept. of Game and Fisheries, Montgomery, Ala.
'33 Regan, C. C., 3920 Tracy Ave., Covington, Ky.
'33 Reid, Kenneth A., Reidmore, Connellsville, Pa.
'93 Reighard, Prof. Jacob E., University of Michigan, Ann Arbor, Mich.
'32 Reinhart, William H., Sandusky, Ohio.
'35 Richan, Fred J., U. S. Fisheries, Bozeman, Mont.
'24 Richard, L. A., Dept. Colonization, Mines and Fisheries, Quebec, Canada.
'36 Richards, W. F., Mason, Mich.
'34 Richardson, Laurence R., Dept. of Zoology, McGill Univ., Montreal, Canada.
'35 Richey, College Station, Texas.
'30 Ricker, William E., Pacific Salmon Research Station, Vedder Crossing, B. C., Canada.
'34 Rivero, Luis Howell, Museo Poey, Universidad de la Havana, Cuba.
'33 Roach, Lee S., Dept. of Conservation, Columbus, Ohio.
'35 Robertson, Alexander, Cultus Lake Hatchery, Vedder Crossing, B. C., Canada.
'35 Robertson, R. W., 2792 Tivoli Ave., Baltimore, Md.
'31 Rochette, Hon. Edgar, Depute de Charlevoix-Saguenay, 81½ Claire Fontaine, Quebec, Canada.
'19 Rodd, J. A., Department of Fisheries, Ottawa, Canada.
'20 Rodd, R. T., Director of Fisheries, Dept. of Lands and Mines, Edmonton, Alberta, Canada.
'35. Rodeheffer, I. A., University Museums, Ann Arbor, Mich.
'33 Roff, George W., U. S. Fisheries, Manchester, Iowa.
'34 Rogers, Carleton, 127 N. Main St., Porterville, Calif.
'32 Roll, Jacob, Glenwood, Minn.
'34 Royce, J. S., Warrensburg, N. Y.
'35 Royce, William F., Comstock Hall, Cornell University, Ithaca, N. Y.
'35 Rumsey, William L., Jr., 128 Vanderbilt Hall, Harvard Medical School, Boston, Mass.
'30 Russ, H. C., State Fish Hatchery, Mumford, N. Y.
'30 Russell, J. R., Box 62, Haverman, Idaho.
'34 Sadler, William O., Mississippi College, Clinton, Miss.
'36 Salter, L. C., 3945 Connecticut Av., N. W., Washington, D. C.

'32 Sanson, William J., Kennedy Lake, Tofino, B. C., Canada.
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'15 Scofield, N. B., Fish and Game Commission, 450 McAllister St., San Francisco, Calif.
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'16 Spragle, L. H., Paradise Brook Trout Co., Cresco, Pa.
'10 Stack, George F., Paradise Brook Trout Co., Cresco, Pa.
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'21 Tresslet, Frederick, Box 26, Thurmont, Md.
'27 Trimpi, William W., 457 Center St., S. Orange, N. J.
'36 Trippensee, R. E., Massachusetts State College, Amherst, Mass.
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'28 Van Oosten, Dr. John, U. S. Bureau of Fisheries, University Museums, Ann Arbor, Mich.
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'36 Ver Duin, Claude, 110 Williams St., Grand Haven, Mich.
'19 Viosca, Percy, Jr., Southern Biological Supply Co., 517 Decatur St., New Orleans, La.
'36 Vladykov, Dr. Vadim D., Chesapeake Biological Laboratory, Solomons Island, Maryland.
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'29 Voizard, Armand, 842 Boulevard Gouin Est., Montreal, Canada.
'34 von Ihering, Dr. Rodolpho, Instituto Biologico, Sao Paulo, Brazil, S. A.
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'36 Wahl, Leif, 4032 - 20th S. W., Seattle, Wash.
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'24 Westerman, Fred A., Department of Conservation, Lansing, Mich.
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'34 Wheeler, F. H., Gray Rocks Inn, St. Jovite Station, P. Q., Canada.
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'34 White, Hon. Smeaton, The Gazette, 1000 St. Antoine St., Montreal, Canada.
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Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Committee (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the Transactions.

I. MECHANICAL DETAILS

1. *Manuscript must be typewritten double-spaced.* Use one side only of sheet. Do not fold manuscript.

2. *Carbon copies will not be accepted.* Do not use thin, transparent paper. Heavy bond paper is preferred

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4. *Pages* must be numbered in consecutive order, including the bibliography, tables, charts, etc.

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6. *Footnotes* should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note.

7. *The title* of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use the word "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least triple space between lines:

REPORT ON THE DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. For *caption* and *identification* follow style in last volume of Transactions.

9. *Underscore* all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of an order higher than the genus. Esocidae; *Esox lucius.*

II. STYLE

10. *Bibliographic references* in text should give name of author and year of publication in parenthesis, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. Do not include any references not mentioned in the text. List authors in alphabetical sequence. Follow the setup given below to be placed at end of paper:

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1899. Report on the disease of brook trout. Trans. Am. Fish. Soc., Vol. 50, pp. 450-461.

Please check carefully your references as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc. against their original sources, after the final typing, and *state beneath your bibliography that this has been done.* Many bibliographic titles published in Transactions have been found to be incomplete and very inaccurate. Help us correct this situation.

11. *Tables.* Abbreviate the word "number" (No.) when referring to a serial number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average," and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column. Note that no vertical lines are used to separate columns!

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75°F., 75° C.

"Number," when preceding figures—No. 125; otherwise spell out.

"United States," if preceding name of a department or a bureau or a vessel, etc.—U. S. Bureau of Fisheries, U. S. S. *Indiana.*

(b) Do not abbreviate the following:

States, cities, etc.

Item	Number of fish	Percentage of total	Average length in millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.05

12. *Capitals.* Capitalize words when used with a name or an identifying number or letter, or when referring to a particular State, Government, etc. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Boulder Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest.

Capitalize names of sections of the United States, as Middle West, but lower-case a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages) preceding Roman numerals, as Article I, Chapter II, Figure IV, Group VI, Age-group II, Plate VIII, etc. Also capitalize such terms as Appendix 1 or Appendix A, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species.

13. *Abbreviations.* (a) Abbreviate the following:

Clock time, if connected with figures —2:30 a.m.

Months

Measures and weight—6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage—12 per cent, a percentage of 25.5.

14. *Numerals.* Spell out all *isolated* numbers which contain one or two digits, but use figures in a group of enumerations when any one number of that group contains more than two digits. Treat alike all numbers in a series of connected groups. For example: There were fifty trout. There were 50 trout, 120 bass, and 5 pike. There were fifty trout, twenty bass, and five pike. There were 50 trout and 20 bass in one can, and 50 trout and 120 bass in the other.

Figures must also be used after a colon in text if matter runs on, irrespective of the number of digits, as: The following shipment was made: 24 trout, 50 bass, and 2 carp.

Do not spell out numbers of three or more digits, and always use a comma in a number of four or more digits.

Use figures for all enumerations of weight, measure, distance (if fraction spell out, as one-half mile), clock time, money, percentage, degree, proportion or ratios, age, dates, decimals, and mixed numbers (spell out common frac-

tions if alone: one-eighth). For example: $3.00 per 20 pounds; 5 feet 6 inches; 6 acres; 4:30 p.m.; 4 o'clock; 25.5 per cent; 75°; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; 4.5 p.p.m.; 0.25; 1 ½ pages.

Write 8 by 12, not 8 x 12 unless multiplication is indicated.

Do not use two figures when two numbers appear together, as ten 12-room houses; twenty 6-inch trout.

Spell out figures beginning a sentence. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout."

Spell out such expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout. Write 50-50, not "fifty-fifty."

15. *Use of hyphen.* Many compound words when used as nouns are not hyphenated but require use of the hyphen when used as adjectives. For example note the following sentences: "This was *cold water.*" "Trout are *cold-water* fish." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. *Condense your paper* to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, direct, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. Papers which are too poorly written will be rejected. Do not expect your Editorial Committee to rewrite your manuscript.

17. *Be definite in references to species.* The scientific name, and wherever needed the complete common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," "trout," "pike," and "pickerel" apply to any one of several species.

18. *Things to Avoid.* The *words* "case," "instance," "show," "found," "gave," and "present" are overworked in manuscripts, the same word sometimes appearing several times in one paragraph.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used. The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *This* was true in every *case. The mortality was high* in every *pond.*

19. *Abstract of Paper.* Give a condensed summary or brief abstract at the beginning of your paper, if at all possible. This is especially desirable for all long papers.

Prepared by Publications Committee
John Van Oosten, Chairman
February, 1937

PART I. SUBJECT INDEX

Abothrium crassum parasitic on speckled trout, Richardson, L. R., 349-351.
Abstracts of papers to be submitted hereafter, 46-47.
Acanthocephala parasitic on Wayne County (Ohio) stream fish, Bangham, R. V., 357-358.
Actinonaias carinata, gravid period and like span, Vander Schalie, Henry, 406-410.
Acts passed by 74th Congress, Fiedler, R. H., 35-36.
Advertising campaigns conducted by Oyster Institute, Association of Pacific Salmon Fisheries and individual concerns, Fiedler, R. H., 36.
Aeration of bottom water released from dams, Hubbs, Carl L. (disc.), 71.
Agamonema sp. parasitic on Johnny darter and green sunfish, Bangham, R. V., 357-358.
Agriculture, Department of: see **U. S. Department of Agriculture.**
Air bladder disease in lake trout fingerlings, Wolf, Louis E., 359-363, 2 plates.
Algae as food for Dauphin pulex, Smith, M. W., 288-289.
  found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 119-124.
Alkalinity and hardness of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 109-110.
Allocreadium ictaluri paraitic on black bullhead, Bangham, R. V., 357-358.
Alloglossidium geminus parasitic on black bullhead, Bangham, R. V., 357-358.
Aluminum content Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 110.
Amblema costata, gravid period and life span, Van der Schalie, Henry, 406-410.
American Fish Policy, report of Committee available in mimeographed form, Wickliff, E. L., 29.
American Fisheries Society, Articles II and IV of By-Laws amended; Article V corrected, 42-43.
  certificate of incorporation, 445.
  committees, 1936-1937, list of members, 4-5.
  constitution and by-laws as amended Sept. 4, 1936, 446-449.
  list of members: honorary, 450; patrons, 450-451; life, 452; active, 453-464; state, 465; clubs, dealers, etc., 465-466; libraries, 466-467; corresponding, 467.
  officers 1935-1936, 3.
  presidents' terms of service and places of meeting, 6-7.
  67th annual meeting to be held Aug. 23-25, 1937, in Mexico City, 43.
  transactions, copies available for sale, 1892-1935, 22.
American Society for the Advancement of Science officially recognizes the American Society of Limnologists as an affiliated society, Hazzard, A. S., 34.
American Society of Limnologists officially affiliated with American Society for the Advancement of Science, Hazzard, A. S., 34.
American Wildlife Institute completed its organization and proposed an International Wildlife Conference, with fisheries biology as important part of program, Hazzard, A. S., 34.
  support of future leaders of fish management desired, Hubbs, Carl L., 55.
Amphipoda as food for young largemouth bass, tabulated, 253-259.
Anax junius, life history notes and control measures, Kingsbury, Oliver R., 268-270.
Anchoviella brownii as food for rock bass, Truitt, R. V., and Vladykov, V. D., 225.
Angling (see also **Fishing**), California system for measuring catch, Croker, Richard S., 301-305.
  report Vice-President Division of, 1935-1936, Locke, S. B., 37-38.
  winter vs. summer effects on given fish populations of Michigan lakes, Hazzard, A. S., and Eschmeyer, R. W., 87-97, map.

Ankistrodesmus as food for Daphnia pulex, Smith, M. W., 288-289.
Annelida as food for young largemouth bass, tabulated, 253-259.
Annual dues increased from $10.00 to $20.00, 42.
Annulus formation period in scales of white crappie, Hansen, Donald F., 227-236, illus.
Antarctic whaling industry, Fiedler, R. H., 436-437.
Aplites salmoides, data on interrelationships between food habits, rate of growth and cannibalism in Michigan rearing ponds, Cooper, Gerald P., 242-265, 4 fig.
Aquatic biologists appointed by federal and state conservation agencies, adequately trained? Hazzard, A. S., 34.
biology and physics, report Vice-President Division of, 1935-1936, Hazzard, A. S., 34.
Arachnida as food for young largemouth bass, tabulated, 253-259.
Articles II and IV of By-laws amended; Article V corrected, 42-43.
Artificial propagation of walleyed pike, Butler, George E., 277-278.
versus natural propagation of commercial species of fish in the Great Lakes region, Smith, Lester, 56-62.
Association of Pacific Salmon Fisheries, advertising campaign, Fiedler, R. H., 36.
Atlantic salmon parr in Newfoundland West Coast rivers, Belding, David L., 211-224.
Atlantic whiting: see **Whiting.**
Auditing, report committee on, 1935-1936, 40.
Audubon Society protecting merfansers (disc.), 341-342.
Babcock, John P., deceased, 48.
Back-swimmer: see **Notonecta.**
Bacteria in newly impounded water, Ellis, M. M., 66-68.
Bacterial infection of lake trout fingerling air bladders, Wolf, Louis E., 359-363, 2 plates.
Bait compared with catch in Fife Lake creel census, Eschmeyer, R. W., 324-334.
Baltimore consumes crab meat from Louisiana while Maryland and Virginia seem unable to develop measures to sustain production of Chesapeake blue crab, Fiedler, R. H., 36.
Bass, largemouth black, yield in Chequamegon National Forest lakes, Elkins, Winston A., 311.
largemouth, introduction into Cuban waters disastrous to native Cyprinodontes, with consequent increase in Anopheles abundance and malaria, Rivero, Luis Howell, 367-368.
largemouth, smallmouth, rock, best weather for biting, Eschmeyer, R. W., 327-329.
predators and their control, Kingsbury, Oliver R., 267-274, 1 fig.
striped, investigations in Chesapeake Bay, Truitt, R. V., and Vladykov, V. D., 225-226.
tapeworm infection in a rearing pond, Langlois, T. H., 364-365.
young largemouth, food habits, growth rate and cannibalism in Michigan rearing ponds, Cooper, Gerald P., 242-265, 4 fig.
Beaver Creek, Ohio, comparative oxygen, bottom organisms and Zooplankton data in impounded water and natural stream low dams (table), 83.
Biological fisheries research, some principles, Schultz, Leonard P., 188-192.
Readjustment Unit, in cooperation with U. S. Bureau of Fisheries, hatchery constructed for stocking Norris Reservoir, Cahn, Alvin R., 399.
Black cod: see **Cod, black.**
Black crappie: see **Crappie, black.**
Bland Bill not passed, Fiedler, R. H., 36.
Blood clots in gills of trout and recommended treatment, Wolf, Louis E., 369-371, 1 fig.
Blue crab fishery, extended development made possible through studies in canning, Fiedler, R. H., 37,

Bluegill, best weather for biting, Eschmeyer, R. W., 327-329.
yield in Chequamegon National Forest lakes, Elkins, Winston A., 312.
Blunt-nosed minnow, generalized feeder, introduction in impounded waters suggested after the plankton drop, Wickliff, E. L., and Roache, Lee S., 80.
Booklet on practical fish cookery and one on oysters published by U. S. Bureau of Fisheries, Fiedler, R. H., 36.
Bothriocephalus claviceps parasitic on smallmouth black bass, Bangham, R. V., 357-358.
Bottom fauna and rainbow trout production in one mile of stream, Surber, Eugene W., 193-202, 1 fig.
material made available for fertilization of shallows by means of suction pump, Hubbs, Carl L. (disc.), 74.
sampler, illustrated, 197.
samples of Michigan lakes obtained with Ekman dredge, Miller, Donald E., 129.
types in Michigan streams and organisms found before and after improvement, tabulated, 183-185.
Boxes superior to barrels for delivery of better quality fish to market, Fiedler, R. H., 37.
Brains inadequate as trout food because of high percentage of cholesterol, Hewitt, Edward R., 292.
Brazil, impounded waters and stocking problems peculiar to the country, Ihering, Rodolpho von (disc.), 75.
Breeding and food habits of Esox lucius and E. vermiculatus, McNamara, Fred, 372-373.
Brevoortia tyrannus as food for bass, Truitt, R. V., and Vladykov, V. D., 225.
British Isles, fresh water fishery problems, Rushton, W., 383-389.
Brook trout: see **Trout, brook.**
Buckskin trout: see **Trout, buckskin.**
Bullfrogs as bass predators, Kingsbury, Oliver R., 271.
Bullhead, weather conditions not affecting bite, Eschmeyer, R. W., 327-329.
Butler, Ray, appreciation, 102.
By-Laws American Fisheries Society as amended, Sept. 4, 1936, 446-449.
report committee on, 1935-1936, 42-43.
Caddis larvae, chiefly Hydropsyche, as food for Cottus bairdii and C. cognatus, Koster, Wm. J., 375.
Caesars Creek, Ohio, comparative Oxygen, bottom organisms and Zooplankton data in impounded water and natural stream low dams (table), 83.
Calcium content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 111.
California, canning of tuna and mackerel greatly increased in 1935, Fiedler, R. H., 35.
fishermen's cooperative covering crabs and sardines, Fiedler, R. H., 35.
sardine fishery, provision for biological study of, proposed legislation not passed, Fiedler, R. H., 36.
sardine reduction into meal and oil on factory ships, Fiedler, R. H., 438.
sardine, resolution regarding, 41.
study of the marketing of fish in the San Francisco Bay area conducted by the U. S. Bureau of Fisheries, Fiedler, R. H., 37.
system for measuring Anglers' catch, Croker, Richard S., 301-305.
Callinectes sapidus as food for bass, Truitt, R. V., and Vladykov, V. D., 225.
Camallanus oxycephalus parasitic on smallmouth black and warmouth bass Bangham, R. V., 357-358.
Cambarus rusticus Girard: see **Crayfish.**
Canadian and United States relationships, settlements and treaties, Thompson, W. F., 24-27.

Cannibalism in bass rearing ponds and its control, Kingsbury, Oliver R., 270-271.
in relation to feeding habits and growth rate in young largemouth bass, Cooper, Gerald P., 242-265, 4 fig.
Canning fish on factory ships, Fiedler, R. H., 432-433.
fish studies opened opportunities for development of sea mussel industry on Atlantic Coast; razor clam industry and an extended blue crab fishery; Fiedler, R. H., 37.
industry and processing fish for market improved during past year, Fiedler, R. H., 34.
Carbon dioxide in impounded waters, Ellis, M. M., 65.
Catch per hour and per species with various methods and baits in Fife Lake, Eschmeyer, R. W., 324-334.
Catfish (Pimelodus clarias) do not reach maturity naturally because of excess fat in Brazilian impounded waters, Ihering, Rodolpho von, 75.
Catte, Eugene, deceased, 48.
Cephalin and lecithin (Factor "H") to replace fresh foods in trout diet, Hewitt, Edward R., 291-297.
Certificate of incorporation, 445.
Cestodes parasitic on speckled trout in Lake Edward, Quebec, Richardson, L. R., 343-356, figured 348; 350.
parasitic on Wayne County (Ohio) stream fish, Bangham, R. V., 357-358.
Chara a food item of Cottus bairdii kumlieni, Koster, Wm. J., 374.
Chemical analyses of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 107-114.
Chequamegon National Forest, Wisconsin, fish study, Elkins, Winston A., 306-312.
Chesapeake Bay sport fishing, Truitt, R. V., and Vladykov, V. D., 403-405.
Bay striped bass investigations, Truitt, R. V., and Vladykov, V. D., 225-226.
blue crab, Maryland and Virginia seem unable to develop measures to sustain the production of, Fiedler, R. H., 36.
Chlorine content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 110.
Chlorophyceae in intestinal tract of Daphnia pulex, Smith, M. W., 288.
Chloresterol in brains causes degeneration and death when fed to trout, Hewitt, Edward R., 292.
Chubs greatly reduced in numbers in Great Lakes, Van Oosten, John, 132.
mesh used in Lake Huron, agreement reached concerning uniform size, Thompson, W. F., 26.
Ciliates in newly impounded waters, Ellis, M. M., 66-68.
Cisco, commercial examination in Great Lakes, Van Oosten, John, 132.
Ciscowet trout: see **Trout,** ciscowet.
Cladocera as food for young largemouth bass, tabulated, 253-259.
food of Daphnia apulex in fertilized water, Smith, M. W., 287-290.
found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 123; 125.
Clinostomum marginatum parasitic on smallmouth black bass, Bangham, R. V., 357-358.
Closed seasons, in most cases should be advanced three to seven days, Smith, Lester, 61.
Cod, black, regarded by Pacific Coast fishermen as much scarcer than formerly, Thompson, W. F., 27.
liver oil found 100 times less potent than swordfish liver oil in vitamins A and D, Fiedler, R. H., 37.
Cold storage trade increased in 1935, Fiedler, R. H., 35.
Cole, C. G., Conservation Officer, gave 1935 census returns for Branch County lakes, Michigan, Hazzard, A. S., and Eschmeyer, R. W., 92-93.
Coleoptera as food for young largemouth bass, tabulated, 253-259.
Color of trout as affected by diet, Hewitt, Edward R., 297.
Columbia (Missouri) Unit of U. S. Bureau of Fisheries, Ellis, M. M., 64.

Commercial fishery industry on Great Lakes, significance, Van Oosten, John, 131.
fishing as influenced by the factory ships, Fiedler, R. H., 427-440.
fishing, report Vice-President Division of, 1935-1936, Fiedler, R. H., 34-37.
Commissioner of Fisheries, Report Progress in Biological Inquiries, 1934, Appendix III, quoted, 25.
Committee, appointment, 38-39; 44.
Auditing, report 1935-1936, 40.
Executive, by-laws concerning, amended, 42-43.
Executive, minutes of meeting, Gordon, Seth, 23.
on American Fish Policy, report available in mimeographed form, Wickliff, E. L., 29.
on Common and Scientific Names of Fishes, 1936-1937 members, 4; note predicting completion of list within year, Hubbs, Carl L., 28; members eligible for election without previous attendance at meetings, 42.
on Foreign Relations, report 1935-1936, Thompson, W. F., 24-27; Election of Committee for ensuing year, 44.
on Nominations, report 1935-1936, 43-47.
on Resolutions, report 1935-1936, 40-42.
on Revision of By-Laws, report 1935-1936, 42-43.
on Study of Pollution, report, Denmead, Talbott, 29-31.
Time and Place, report 1935-1936, 43.
Committees, appointment of, 38-39; 44.
Commodore Perry and protection of American whalers in Japan, Fiedler, R. H., 434-435.
Common and scientific names of fishes, committee: see Committee.
Conservation officers collecting data of Ohio impounded waters, Wickliff, E. L., and Roach, Lee S., 74-75.
Constitution and by-laws of the American Fisheries Society, as amended Sept. 4, 1936, 446-449.
changes in Articles II, IV and V proposed and carried, 42-43.
Conventions and treaties, resolution regarding, 40-41.
Conveyor, Warner-Bower, for surmounting dams, Bower, E. A., 411-414, 2 fig.
Coolidge, Charles A., deceased, 48.
Cooper, Gerald P., made estimates of the fish population of southern Michigan lakes, Hazzard, A. S., and Eschmeyer, R. W., 94.
Cooperation between government and states results in fish increase, Earle, 392-394.
with State and Federal agencies, resolution regarding, 41.
Cooperative societies in Maine, North Carolina and Pacific Coast, Fiedler, R. H., 35.
Copepoda as food for young largemouth bass, tabulated, 253-259.
found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 123; 125.
Corallobothrium fimbriatum parasitic on black bullhead, Bangham, R. V., 357-358.
Cottus bairdii bairdii, C. b. kumlieni and C. cognatus, stomach analyses, Koster, Wm. J., 374-382.
Crab canneries on Japanese factory ships, Fiedler, R. H., 432-433.
Chesapeake blue, Maryland and Virginia seem unable to develop measures to sustain the production of, Fiedler, R. H., 36.
Crabs and sardines, cooperative societies for sale of, formed in California, Fiedler, R. H., 35.
Crappie, black, yield in Chequamegon National Forest lakes, Elkins, Winston A., 311-312.
Crappies, 500 planted in Meander Lake in 1932; 116,000 taken out in 1935, Roach, Lee S. (disc.), 71.
Crater Lake: see Lake, Crater.

Crayfish, Cambarus rusticus Girard, habits, Langlois, T. H., 275-276.
French, introduction into United States desirable, Hewitt, E. R. (disc.), 276.
Creel census data for Michigan lakes, Hazzard, A. S., and Eschmeyer, R. W., 87-97.
census on Fife Lake, Michigan, Eschmeyer, R. W., 324-334, 1936.
Crepidostomus cooperi parasitic on warmouth bass and green sunfish, Bangham, R. V., 357-358.
cornutum parasitic on smallmouth black and rock bass, Bangham, R. V., 357-358.
fausti Hunninen and Hunter, parasitic in speckled trout, described, Richardson, L. R., 345; figured 348.
isostomum parasitic on trout perch, Bangham, R. V., 357-358.
solidum, characters distinguishing it from C. fausti are given, Richardson, L. R., 347.
Crepotrema funduli parasitic on brook stickleback, Bangham, R. V., 357-358.
Crytogonimus chyli parasitic on smallmouth black rock bass, Bangham, R. V., 357-358.
Cuba, increase in malaria precipitated through introduction of bass and consequent depletion of mosquito-eating Cyprodontes, Rivero, Luis Howell, 367-368.
Cultus Lake Hatchery, Canada, experiments with gravel hatching of sockeye salmon eggs, Robertson, Alexander, 279-282.
Cuyahoga River, Ohio, comparative oxygen, bottom organisms and Zooplankton data in impounded water and natural stream low dams (table), 83.
Cysts in speckled trout caused by Diphyllobothriid larva in Lake Edward, Richardson, 351-352.
Dam, Passamaquoddy: see **Passamaquoddy.**
Dams, beneficial effects of roller type, with opening at bottom, Ellis, M. M., 66.
low, with weir or "V" notch recommended, Wickliff, E. L., and Roach, Lee S., 83-84.
new "subsurface" type in experimental stage in Ohio, Wickliff, E. L., and Roach, Lee S., 84.
Norris, Weeler, etc., of Tennessee Valley, Cahn, Alvin R., 398-401.
surmounted by means of Warner-Bower fish conveyor, Bower, E. A., 411-414.
Daphnia magna regarded as first intermediate host of the bass tapeworm, Langlois, T. H., 364-365.
pulex in fertilized water, notes on food, Smith, M. W., 287-290.
Deason, H. J., appreciative mention, Van Ooston, John, 161.
Decapoda as food for young largemouth bass, tabulated, 253-259.
Deflectors, changes produced by, tabulated, 180.
Detritus with bacteria as food for Daphnia pulex, Smith, M. W., 287-290.
Diatoms found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 119-122.
Diet as factor in checking diseases of fish, Kingsbury, Oliver R., 273.
Diphyllobothriid larva parasitic on speckled trout, Richardson, L. R. 351; figured 348.
Diptera a food item of Cottus bairdii and C. cognatus, Koster, Wm. J., 374-379.
larvae and adults as food for young largemouth bass, tabulated, 253-259.
Disease in trout characterized by blood clots in gills, and recommended treatment, Wolf, Louis E., 369-371, 1 fig.
Diseases in rearing ponds, diet as factor, Kingsbury, Oliver R., 273.
Dispersal of smelt in the Great Lakes Region, Van Oosten, John, 160-170.
Don Martin Reservoir, Northern Mexico, Ellis, M. M., 63.
Drag net fishery for flounders and soles is steadily growing on Pacific Coast, Thompson, W. F., 27.
Dry River, New Hampshire, creel census, Smith, Osgood R., 313-315.
Ducks, Merganser and Golden-eyes, extent of damage in Michigan rearing ponds, Beach, U. Sidney, 338-341.

Merganser, depredations in Michigan trout waters, Leonard, J. W., and Shetter, David S., 335-337.
Dues for annual state membership increased from $10.00 to $20.00, 42.
Duke University sponsored study of the marketing of fish in Durham, North Carolina, Fiedler, R. H., 36-37.
Duty on frozen swordfish raised fifty per cent, Fiedler, R. H., 36.
Dytiscus in fish ponds controlled by spraying one part cod liver oil to three parts gasoline, Kingsbury, Oliver R., 267-268.
Echinorhynchus lateralis Leidy 1851, parasitic on speckled trout, redescribed, Richardson, L. R., 354; figured, 350.
Economic studies of the marketing of fish sponsored by the Florida fishery agency, Duke University and U. S. Bureau of Fisheries conducted in 1935, Fiedler, R. H., 36-37.
Egg-laying habits of the crayfish, Cambarus rusticus Girard, Langlois, T. H., 275.
Eggs found in stomach analyses of Cottus bairdii and C. cognatus, Koster, Wm. J., 375-382.
of sockeye salmon, advantages of gravel-hatching, Robertson, Alexander, 279-282.
of walleyed pike, treatment in artificial propagation, Butler, George E., 277-278.
Election of Officers, Vice-Presidents of Divisions; Committees on Foreign Relations and on Common and Scientific Names of Fishes, 43-44.
Elephan Butte Reservoir, New Mexico, lake type of impounded water, Ellis, M. M., 69.
England (see also **British Isles**), factory ships for freezing fish at sea, Fiedler, R. H., 431-432.
impounded reservoirs not conducive to good fishing, Rushton, W. (disc.), 85-86.
Ephemerida a food item of Cottus bairdii and C. cognatus, Koster, Wm. J., 372-379.
Ephemeroptera as food for young largemouth bass, tabulated, 253-259.
Erosion silt: see **Silt**.
Esox lucius and E. vermiculatus, breeding and food habits, McNamara, Fred, 372-373.
Eubothrium salvelini (Schrank, 1790), parasitic on speckled trout, described, Richardson, L. R., 349; figured, 348.
Executive Committee, by-laws concerning, amended, 42-43.
Exotic bass introduced into Cuban waters resulted in depletion of Cyprodontes and consequent outbreak of malaria, Rivero, Luis Howell, 367-368.
forms, introduction into Great Lakes not recommended, Van Oosten, John, 138.
rainbow trout introduced into Fish Lake has resulted in depletion of native species, Madsen, David H., 396.
Factory ships, their significance in trade and commerce, Fiedler, R. H., 427-440.
Federal aid in control of pollution discussed, Denmead, Talbott, 30-31.
and state agencies, resolution regarding cooperation, 41.
government and Muskingum Watershed Conservancy District constructing eleven large flood control reservoirs in Ohio, Wickliff, E. L., and Roach, Lee S., 84-85.
Feeding habits in relation to size dispersal, beginning of cannibalism and rate of growth in young largemouth bass, Cooper, Gerald P., 242-265, 4 fig.
of sculpins in relation to trout, Koster, Wm. J., 379-382.
Fertilization of impounded waters (disc.), 71-72.
of shallows with material obtained from bottom by means of suction pump, Hubbs, Carl L., (disc.), 74.
or liming of small lakes or bays recommended before flooding to facilitate bottom decay and aid maturity, Wickliff, E. L., and Roach, Lee S., 81.
Fife Lake: see **Lake, Fife**.
Fish consciousness in the public desirable through radio, newspaper and magazine propaganda, Schultz, Leonard P., 189.
consumed in 1935 greater than in 1934, Fiedler, R. H., 35.
cookery booklet published by U. S. Bureau of Fisheries, Fiedler, R. H., 36.

culture, report Vice-President Division of, 1935-1936, Langlois, T. H., 32-33.
culture, text book desirable, Bost, J. E., 298.
degree of freshness determined by new technique developed by Bureau of Fisheries, Fiedler, R. H., 37.
exotic species should not be stocked in lakes and streams of National Parks, Hubbs, Carl L., 53.
management, future of, Hubbs, Carl L., 51-55.
Fisheries program in the Tennessee Valley, Cahn, Alvin R., 398-401.
Research Commission established in Newfoundland, Thompson, W. F., 24.
Fishery cooperative in Maine, North Carolina, and Pacific Coast, Fiedler, R. H., 35.
industry, fresh and frozen-packed, 1935 a record year, Fiedler, R. H., 35.
problems in impounded waters, Ellis, M. M., 63-71.
Fishing (see also **Angling**; **Drag-net** fishery; **Line** fishing; **spearing**), commercial, report Vice-President Division of, 1935-1936, Fiedler, R. H., 34-37.
for sport and reduction of kill recommended to anglers, Locke, S. B., 38.
for sport, importance in Maryland, Truitt, R. V., and Vladykov, V. D., 403-405.
gear, agreement reached concerning uniform size of mesh used for chubs in Lake Huron, Thompson, W. F., 26.
gear, experimental study in Great Lakes, Van Oosten, John, 137.
gear, increased size of mesh recommended by North American Council on Fisheries Investigation for preservation of haddock fishery, Thompson, W. F., 25.
gear, size of mesh for lake trout, whitefish and yellow pike-perch spawn-fishing, Smith, Lester, 60-61.
in Michigan lakes, summer vs. winter, Hazzard, A. S., and Eschmeyer, R. W., 87-97, map.
results compared in trolling, casting and still-fishing with artificial and natural bait in varying weather, Eschmeyer, R. W., 324-334.
Flood control in Ohio, eleven large dams being constructed by Federal Government and Muskingum Watershed Conservancy District, Wickliff, E. L., and Roach, Lee S., 84-85.
Florida State Fishery Agency sponsored survey of the marketing of fish by Florida fishermen, Fiedler, R. H., 36.
Flounder drag net fishery on Pacific Coast steadily growing, Thompson, W. F., 27.
Flukes parasitic on Wayne County (Ohio) stream fish, Bangham, R. V., 357-358.
Food and breeding habits of Esox lucius and E. vermiculatus, McNamara, Fred, 372-373.
for fish, stomach contents of trout from test area tabulated, 197.
for humans, outstanding qualities of Atlantic whiting, Bean, D. A., Clague, J. A., and Fellers, C. R., 415-421.
Forage fish recommended for newly impounded waters since during the initial year the plankton content is high; after the plankton drop, the adults will feed primarily on algae, Wickliff, E. L., and Roach, Lee S., 80.
Foreign Relations Committee, report 1935-1936, Thompson, W. F., 24-27.
Fort Francis, sewage pollution, Thompson, W. F., 26.
France, factory ships for freezing fish at sea, Fiedler, R. H., 430-431.
Fraser River, treaty with Canada for rehabilitation of sockeye run, Thompson, W. F., 24-25.
Freezing and cold storage trade increased in 1935, Fiedler, R. H., 35.
Freezing and icing fish on factory ships, Fiedler, R. H., 429-432.
Freshness of fish determined by new technique developed by Bureau of Fisheries, Fiedler, R. H., 37.
Fresh water fish management, future of, Hubbs, Carl L., 51-55.
Fry, planting of commercial species should be made in waters from which the eggs were taken, Smith, Lester, 61.
Fungus growth (Sphaerotilis natans) caused by effluent from cider factory, Rushton, W., 387-388.

Furunculosis checked through feeding Hewitt's trout food, Lincoln, Guy (disc.), 390.
in the British Isles, Rushton, W., 386.
possibly introduced into Europe from America, Davis, H. S., (disc.), 389.
Gangs of gill nets for each boat fishing for hatcheries should not exceed two, with a limit of 22,000 feet per gang, Smith, Lester, 60.
Gear: see **Fishing** gear.
Geneva multilateral whaling convention of 1931 ratified by act of 74th Congress and approved by President, May 1, 1936, Thompson, W. F., 24.
Geographical survey of Michigan lakes, Miller, Donald E., 128-130.
Germany's "Terje Viken" whaling vessel largest factory ship, Fiedler, R. H., 437.
Gill disease of trout, and recommended treatment, Wolf, Louis E., 369-371, 1 fig.
Gill-net mesh: see **Fishing** gear.
Gill rakers, vertebrae and pyloric appendages of salmon parr, tabulated, 222.
Gizzard shad: see **Shad**, gizzard.
Glugeau hertwigi parasitic on Osmerus mordax did not transmit infection when speckled trout fed on the smelt, Richardson, L. R., 345.
Golden **shiner** (see also **Notemigonus** crysoleucas), as forage in bass ponds, Cooper, Gerald P., 264-265.
spawning retarded by cold water (disc.), Cooper, Gerald P., 265; Kingsbury, O. R., 266.
Government: see **Cooperation** between government and states.
Gravel, advantages presented in hatching of sockeye salmon eggs, Robertson, Alexander, 279-282.
in rearing-station raceways, advantages and disadvantages, Savage, James, 283-286.
Great **Lakes** (see also Lake), depletion of important species causes rosefish and whiting from Atlantic Coast to be consumed in large quantities in mid-west, Fiedler, R. H., 36.
fisheries: their proper management for sustained yields, Van Oosten, John, 131-139.
natural versus artificial propagation of commercial species of fish, Smith, Lester, 56-62.
spread of the sea lamprey, Hubbs, Carl L., and Pope, T. E. B., 172-176.
Growth rate in relation to feeding habits and cannibalism in young largemouth bass, Cooper, Gerald P., 242-265, 4 fig.
of brook trout, statistics, Shetter, David S., 206-209.
Haddock fishery, treaty for the preservation of, recommended by North American Council on Fisheries Investigations, Thompson, W. F., 25.
Halibut fishery and industry, economic study conducted by the U. S. Bureau of Fisheries, Fiedler, R. H., 37.
treaties outstandingly successful, Thompson, W. F., 27.
treaty with Canada, Thompson, W. F., 25.
Hankinson, T. L., deceased, 48.
Harkness, William J. K., appreciative mention, Van Oosten, John, 161.
Hatcheries, literature furnished the visiting public advised, Earle, Swepson, 392-394.
Hatchery versus natural propagation of fish, Smith, Lester, 56-62.
work in North America (letter), Rushton, W., 390-391.
Hatching of sockeye salmon eggs, advantages of gravel, Robertson, Alexander, 279-282.
Hazzard, A. S., appreciative mention, van Oosten, 160.
Hemiptera as food for young largemouth bass, tabulated, 253-259.
Heron depredations (disc.), 342.
great blue specimen, in one hour took 73 two-and-a-half-inch bass from rearing pond, Kingsbury, Oliver R., 271.
Hewitt's trout food proved reliable check on furunculosis outbreaks, Lincoln, Guy (disc.), 390.
Homoptera as food for young largemouth bass, tabulated, 253-259.

Hubbs, Carl L., appreciative mention, Van Oosten, John, 160.
Huntsman, A. G., elected President, 44; opening speech, 45-46.
Huro salmoides introduced into Cuban waters depleted the native cyprodontes with a consequent disastrous increase in Anopheles and hence malaria, Rivero, Luis Howell, 367-368.
Hyalella knickerbocker probably secondary host of Echinorhynchus lateralis, Richardson, L. R., 355.
Hydrodictyon as menace in bass ponds, Kingsbury, Oliver R., 271-272.
Hydrogen-ion concentration: see pH.
Hymenoptera as food for young largemouth bass, tabulated, 253-259.
Ice-covered lakes, winter conditions improved by cutting ice and making channels from shallow bays and swampy areas to open, oxygenated water, Wickliff, E. L., and Roach, Lee S., 82.
Ice, migration of fish beneath, Aitken, W. W., 98-103, map.
Icing and freezing fish on factory ships, Fiedler, R. H., 429-432.
Ichthyology and limnology courses added to the curricula of certain colleges, Hazzard, A. S., 34.
Import duty on frozen swordfish raised fifty per cent, Fiedler, R. H., 36.
Impounded waters, fertilization (disc.), 71-72.
fishery problems, Ellis, M. M., 63-71.
in England, not conducive to good fishing, Rushton, W. (disc.), 85-86.
of Ohio, studies of, Wickliff, E. L., Roach, Lee S., 76-85, 3 fig.
of Tennessee Valley, fisheries program, Cahn, Alvin R., 398-401.
productivity peak (disc.), 72-73.
restoration of productive conditions of artificial and natural lakes through cooperation of U. S. Department of Agriculture desirable, Markus, Henry C. (disc.), 73.
Warner-Bower conveyor permits selection of fish as the dam is surmounted, Bower, E. A., 413.
Infection (see also Parasites), of air bladder in lake trout fingerlings, Wolf, Louis E., 359-363, 2 plates.
Infusoria found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 119-122.
In Memoriam, 48.
Insect larvae decrease to a minimum in pools of great depth, Wickliff, E. L., and Roach, Lee S., 83.
Insects formed 90% of food of Cottus bairdii bairdii, Koster, Wm. J., 375.
terrestrial, as food for trout during summer period, Surber, Eugene W., 201.
International agreement on Great Lakes management urgently needed, Van Oosten, John, 133-134.
cooperation, resolution regarding, 40-41.
Council for the Exploration of the Sea, and North American Council on Fishery Investigations, growing cooperation between, Thompson, W. F., 24.
Fact-Finding Commission to investigate pike-perch fisheries of Lake Champlain, mentioned, Thompson, W. F., 26.
Falls, sewage pollution, Thompson, W. F., 26.
Fisheries Commission between U. S. and Mexico recommended, Thompson, W. F., 27.
relations, practical means of laying a foundation for future peace, Thompson, W. F., 28.
Wildlife Conference, research in fisheries biology played prominent part in technical program, Hazzard, A. S., 34.
Introduction of bass in Cuba resulted in depletion of Cyprodontes and consequent outbreak of malaria, Rivero, Luis Howell, 367-368.
of exotic species detrimental to native trout in National Parks, Madsen, David H., 395-397.
Iron bacteria found in Minnesota pond (table), 119.
content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 110.

Italy, factory ship for freezing fish at sea, Fiedler, R. H., 431.
Japan, cannery vessels and trawlers for canning crab and manufacturing fish meal and oil from trash fish, Fiedler, R. H., 433.
factory ships for freezing shrimp in Gulf of California, Fiedler, R. H., 432.
Kingfisher depredations (disc.), 342.
Labidesthes sicculus in stomach of Esox lucius, McNamara, Fred, 373.
Lake, American Legion, in Black Hills of South Dakota, pond-type of impounded water, Ellis, M. M., 69.
and stream improvement in National Parks should not include introduction of exotic species, Hubbs, Carl L., 53.
and stream pollution, resolution regarding, 41-42.
Crater, dissolved oxygen high and carbonates and ionizable salts low all through the 2,000 feet of water, Ellis, M. M., 66.
Crescent, Michigan, results of intensive winter fishing census tabulated, 93.
Davenport, beneficial effect of roller type dam, Ellis, M. M., 66.
Edward, Quebec, parasites of speckled trout described, Richardson, L. R., 343-356, 11 fig.
Enemy Swim, South Dakota, Ellis, M. M., 64.
Erie cisco fishery wiped out commercially, Van Coston, John, 132.
Erie fishery regulations, international commission governed by a treaty with Canada recommended by Advisory Committee, Thompson, W. F., 26.
Fife, Michigan, a second season of creel census, Eschmeyer, R. W., 324-334.
Fish, Utah, planting of rainbow trout has resulted in depletion of native species through hybridization, Madsen, David H., 396.
Grand, Michigan, results of intensive winter fishing census tabulated, 93.
Hess, Michigan, results of intensive winter fishing census tabulated, 93.
Higgins, Michigan, results of intensive winter fishing census tabulated, 93.
Houghton, Michigan, results of intensive winter fishing census tabulated, 93.
Houghton, closed period to protect the great northern pike and walleyes during spawning (rather than elimination of winter fishing) recommended, Hazzard, A. S., and Eschmeyer, R. W., 96.
Hubbard, Michigan, results of intensive winter fishing census tabulated, 93.
Huron, increased abundance of yellow pike-perch in relation to artificial propagation, Hile, Ralph, 143-159.
Huron, uniform regulations of commercial fisheries discussed at Toronto conference, Thompson, W. R., 26.
Independence, Michigan, results of intensive winter fishing census tabulated, 93.
Kamloops, British Columbia, Ellis, M. M., 64.
Keokuk, river type of impounded water, Ellis, M. M., 69.
Long, Michigan, results of intensive winter fishing census tabulated, 93.
Lower Hamlin, Michigan, results of intensive winter fishing census tabulated, 93.
Manistee, Michigan, results of intensive winter fishing census tabulated, 93.
Margrethe, Michigan, results of intensive winter fishing census tabulated, 93.
Meander, dissolved oxygen chart, 79.
Meander, a natural hatchery with list of breeder fish, Wickliff, E. L., and Roach, Lee S., 78-80.
Meander, increase of stocked fish, Roach, Lee S., (disc.), 71.
Michigan, blackfin now commercially extinct, Van Oosten, John, 132.
Michigan (Green Bay), biological and economical importance of smelt, Schneberger, Edward, 139-142.
Michigan, increased abundance of yellow pike-perch in relation to artificial propagation, Hile, Ralph, 143-159.
Murray, South Carolina, Ellis, M. M., 63.
Muskallonge, Michigan, results of intensive winter fishing census tabulated, 93.
N. Manistique, Michigan, results of intensive winter fishing census tabulated, 93.
Ocqueoc, Michigan, results of intensive winter fishing census tabulated, 93.
of the Ozarks, Missouri, fish killed by catastrophic change in temperature forcing carbon-dioxide rich slackwater upstream, Ellis, M. M., 65-66.

of the Woods, pollution in, Thompson, W. F., 26.
Ontario, bloater now commercially extinct, Van Oosten, John, 132.
O'Shaughnessy, silted 6% of its original volume in ten years, Wickliff, E. L., and Roach, Lee S., 81.
Pickerel, Michigan, results of intensive winter fishing census tabulated, 93.
Quinault, Michigan, results of intensive winter fishing census tabulated, 93.
Saint Marys, work on removal of cattails, construction of channels, and planting of non-emergent vegetation, Wickliff, E. L., and Roach, Lee S., 82.
Superior, bluefin commercially extinct, Van Oosten, John, 132.
Tocoa, Georgia, finest body of impounded water examined, Ellis, M. M., 66.
trout: see **Trout,** lake.
Wamplers, Michigan, results of intensive winter fishing census tabulated, 93.
W. Twin, Michigan, results of intensive winter fishing census tabulated, 93.
West Okobojii, Iowa, fish movement under ice, Aitken, W. W., 98-103, map.
Wheeler area fisheries program, Cahn, Alvin R., 400-401.
Wilson, Alabama, beneficial effect of roller type dam, 66.
Wilson, example of river type of impounded waters, Ellis, M. M., 69-70.

Lakes, artificial: see **Impounded waters.**
Lamprey, sea (Petromyzon marinus), spread in Great Lakes, Hubbs, Carl L., and Pope, T. E. B., 172-176.
Lampsilis vertricosa, gravid period and life span, Van der Schalie, Henry, 406-410.
Largemouth black bass: see **Bass,** largemouth black.
Laws and regulations (see also **By-Laws; Conventions** and **Treaties),** for whaling industry (see **Multilateral Convention).**
international, or at least interstate control urgently needed in Great Lakes area, Van Oosten, John, 133-134.
Robinson-Patman Act, Social Security Act, Act to give effect to the Whaling Convention and a Ship Subsidy Act passed by 74th Congress, Fiedler, R. H., 35-36.
Lebouria cooperi parasitic on Luxilus cornutus, Bangham, R. V., 357-358.
Lecithin and cephalin (Factor "H") to replace fresh foods in trout diet, Hewitt, Edward R., 291-297.
Leech, Piscicola punctata, parasitic on Wayne County (Ohio) stream fish, Bangham, R. V., 357-358.
Legislation regarding whale industry: see **Multilateral convention.**
Leptothrix ochracea in Minnesota pond (table), 119.
Librarian's report, 1936, 21-22.
Library members of American Fisheries Society, 466-467.
Life-history studies desirable for "buckskin trout," ciscowet trout and the small red-meated trout which spawns in northern Green Bay ten days later than the common lake trout, Smith, Lester, 61.
Limnological equipment presented to Ohio University and Akron University for accumulation of data and training of men, Wickliff, E. L., and Roach, Lee S., 85.
Limnologists, American Society of, recognized officially as affiliated with American Society for the Advancement of Science, Hazzard, A. S., 34.
Limnology and Ichthyology courses added to the curricula of certain colleges, Hazzard, A. S., 34.
Line fishing catches compared with spearing (table), 89.
Literature to be distributed to visiting public at hatcheries advised, Earle, Swepson, 392-394.
Liver oil of Merluccius bilinearis, Bean, D. A., Clague, J. A., and Fellers, C. R., 419-421.
Lonergan bill discussed, Denmead, Talbott, 30-31.
MacDonald, Alexander, deceased, 48.
Mackerel, more canned in California in 1935 than in any previous year, Fiedler, R. H., 35.

Macocheek Creek, Ohio, comparative oxygen, bottom organisms and Zooplankton data in impounded water and natural stream low dams (table), 83.
Maine, cooperative society for outlet of catches of inshore fisherman, Fiedler, R. H., 35.
Malaria increase in Cuba due to introduction of bass and consequent depletion of native mosquito-eating Cyprodontes, Rivero, Luis Howell, 367-368.
Mallards: see **Ducks,** mallard.
Management of Great Lakes fisheries inadequate so long as control remains divided; international or at least interstate regulations urgently needed, Van Oosten, John, 133-134.
Manganese content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 110.
Manuscripts, suggestions for preparing and editing, 468-470.
Mapping Michigan lakes, Miller, Donald E., 128-130.
Maryland, sport fishing, Truitt, R. V., and Vladykov, V. D., 403-405.
Maskinonge as influenced by vegetation in Trent Valley canal system (Ontario), Harkness, W. J. K., (disc.), 74-75.
Maumee River, Ohio, comparative oxygen, bottom organisms and Zooplankton data in impounded water and natural stream low dams (table), 83.
Meander Lake: see **Lake,** Meander.
M. E. C. W., Parks E. C. W., Resettlement Administration and U. S. Forest Service cooperating in survey of Michigan lakes, Miller, Donald E., 128-130.
Meeting of American Fisheries Society to be held next in Mexico City, August 23-25, 1937, 43.
Members attending 66th Annual Meeting at Grand Rapids, Michigan, 1936, list, 15-16.
Membership dues increased from $10.00 to $20.00 for annual state membership, 42.
Membership of American Fisheries Society: see **American Fisheries Society,** list of members.
Menhaden industry adopts new method for preserving fish aboard vessels while fishing at sea, Fiedler, R. H., 37.
Menominee River, smelt taken in 1936 at Marinette, Wisconsin, valued at $65,000.00, Schenberger, Edward, 141.
Merluccius bilinearis: see **Whiting.**
Mesh: see **Fishing gear.**
Mexico and U. S. formation of International Fisheries Commission recommended, Thompson, W. F., 27.
Don Martin Reservoir, Ellis, M. M., 63.
Miami-Erie Canal, Ohio, comparative oxygen, bottom organisms and Zooplankton in created pool (table), 83.
Michigan lake surveys, Miller, Donald E., 128-130.
lakes, comparison of winter and summer fishing, Hazzard, A. S., and Eschmeyer, R. W., 87-97, map.
rearing ponds, interrelationships between food habits, growth rate and cannibalism in Aplites salmoides, Cooper, Gerald P., 242-265, 4 fig.
state, Ontario and U. S. Bureau of Fisheries conference held at Toronto, March 16-17, 1936, Thompson, W. F., 26.
trout stream improvement, experimental evidence, Tarzwell, Clarence M., 177-187.
Migration (see also **Dispersal**), of brook trout in the North Branch of the Au Sable River, Michigan, Shetter, David S., 204-206.
of fish under ice, Aitken, W. W., 98-103, map.
of schools or races of fish in Great Lakes, or one homogeneous population to be determined through tagging, Van Oosten, John, 136-137.
of tagged fish (disc.), 319-320.
Milton Reservoir, Ohio, planting of submerged vegetation partially successful, Wickliff, E. L., and Roach, Lee S., 82.

Mimeographed report of Committee on American Fish Policy available, Wickliff, E. L., 29.
Minnesota fish ponds, physical and chemical analyses; plankton study, Surber, Thaddeus, and Olson, Theodore A., 104-127.
Mississippi impoundments, analyses of bottom mud showed 6% content of kheldahl nitrogen (disc.), 74.
Mud Lake Irrigation Reservoir, Idaho, Ellis, M. M., 68.
Multilateral Convention for the Regulation of Whaling signed by twenty-six nations became effective January 1935, Fiedler, R. H., 437.
Muskallunge yield in Pike-Round Lake waters, Wisconsin, Elkins, Winston A., 310-311.
Muskingum Watershed Conservancy District, Ohio, building eleven large dams with aid of Federal Government, Wickliff, E. L., and Roach, Lee S., 84-85.
Mussel conservation in relation to pearl button industry, Van de Schalie, Henry, 406-410.
industry on Atlantic coast, Fiedler, R. H., 37.
National legislation: see **Laws and regulations.**
National Park Service, in cooperation with Michigan Emergency Conservation Work, made records of fishing for various seasons, Hazzard, A. S., and Eschmeyer, R. W., 88.
Parks, protection of native fishes, Madsen, David H., 395-397.
Research Council allotted biology, Hazzard, A. S., 34.
Natural versus artificial propagation of commercial species of fish in the Great Lakes region, Smith, Lester, 56-62.
Near, W. W., deceased, 48.
Neascus ambloplitis parasitic on smallmouth black and rockbass, Bangham, R. V., 357-358.
vancleavei parasitic on stone roller, common shiner and rock bass, Bangham, R. V., 357-358.
Nematode parasites of speckled trout in Lake Edward, Richardson, L. R., 343-356, illus.
Nematodes parasitic on Wayne County (Ohio) stream fish, Bangham, R. V., 357-358.
Neoechinorhynchus crassius parasitic on stone roller and quillback, Bangham, R. V., 357-358.
Newfoundland, Atlantic salmon parr of the West Coast rivers, Belding, David L., 211-224.
Fisheries Research Commission established, Thompson, W. F., 24.
New Hampshire, White Mountains National Forest, creel census from Dry River, Smith, Osgood R., 313-315.
New Species of nematode: Philomena salvelini, parasitic on Salvelinus fontinalis in Lake Edward, Quebec, Richardson, L. R., 353.
Nitrogen and phosphate levels in newly impounded waters, Ellis, M. M., 66-68.
content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 113-114.
Nominations, report committee on, 1935-1936, 43-47.
Norris Reservoir area, fisheries program, Cahn, Alvin R., 398-401.
North American Council on Fishery Investigations and International Council for the Exploration of the Sea, growing cooperation between, Thompson, W. F., 24.
on Fishery Investigations has new member: Newfoundland Fisheries Research Commission, Thompson, W. F., 24.
on Fisheries Investigations, treaty for preservation of haddock fishery recommended, Thompson, W. F., 25.
North Carolina, cooperative society formed and operated in 1935, Fiedler, R. H., 35.
North Central States Conference of Wildlife Technicians organized at Urbana to facilitate and coordinate research in fish and game, Hazzard, A. S., 34.

Northern pike: see **Pike, northern.**
Norway, antarctic whaling vessels, Fiedler, R. H., 436-437.
Notemigonus crysoleucas as food for young largemouth bass, tabulated, 255-256.
crysoleucas, growth rate tabulated, 246.
Notonecta controlled through repeatedly spraying ponds with one part cod liver oil to three parts of gasoline, Kingsbury, Oliver R., 267.
Nova Scotian Shelf, submarine physiography and oceanographical problems, Hachey, H. B., 237-241, map.
Oceanographical problems and physiography of Nova Scotian Shelf, Hachey, H. B., 237-241, map.
Octomitus salmonis Moore parasitic on speckled trout in Lake Edward, Quebec, Richardson, L. R., 343-344.
Octospinifer macilentus parasitic on white sucker and red horse sucker, Bangham, R. V., 357-358.
Odonata as food for young largemouth bass, tabulated, 253-259.
Officers American Fisheries Society for 1935-1936, 3; Election of officers for ensuing year, 44.
Ohio, impounded waters and stream improvement, Wickliff, E. L., and Roach, Lee S., 76-85, 3 fig.
Oil from the swordfish liver found to be the most potent in vitamins A and D (100 times more potent than the U. S. P. standard reference cod liver oil), Fiedler, R. H., 37.
from whales, produced on factory ships, Mottley, C. McC., 433-437.
O'Malley, Henry, brief biography and appreciation, 40; In Memoriam, 48.
Oncorhynchus nerka Kennerlyi, introduced into Flathead Lake, threatens to invade National Park waters, Madsen, Davis H., 396-397.
Ontario, Michigan and U. S. Bureau of Fisheries conference held at Toronto, March 16-17, 1936, Thompson, W. F., 26.
participates in Washington, D. C., conferences for improved Lake Erie fishery regulations, Thompson, W. F., 26.
Organic detritus and erosion silt in impounded waters, Ellis, M. M., 64-66.
Osmerus mordax dispersal in the Great Lakes region, Van Oosten, John, 160-170.
food habits, fecundity and growth, commercial value, Schneberger, Edward, 139-142.
Ostracoda as food for young largemouth bass, tabulated, 253-259, found in Minnesota pond (table), 125.
Oxygen content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 107-108.
quantity of dissolved in impounded waters, Ellis, M. M., 65.
Oyster Institute, advertising campaign, Fiedler, R. H., 36.
producers of Washington State considering formation of cooperative society for outlet of their product, Fiedler, R. H., 35.
U. S. Bureau of Fisheries published booklet on, Fiedler, R. H., 36.
Pacific Coast cooperatives of salmon fishermen continue to function, Fiedler, R. H., 35.
fisheries, creation of International Fisheries Commission with Mexico recommended, Thompson, W. F., 27.
Pacific Salmon Fisheries Association advertising campaign, Fiedler, R. H., 36.
Parasites (see also Tapeworm), of speckled trout in Lake Edward, Quebec, Richardson, L. R., 343-356, 11 fig.
of Wayne County (Ohio) stream fish, Bangham, R. V., 357-358.
Parks, E. C. W., M. E. C. W., Resettlement Administration and U. S. Forest Service cooperating in survey of Michigan lakes, Miller, Donald E., 128-130.
National, lake and stream improvement should tend towards restoration of natural conditions and introduction of exotic species of fish should be avoided, Hubbs, Carl L., 53.

Parr, salmon, age, growth and characteristics in West Coast rivers of Newfoundland, Belding, David L., 211-224.
Passamaquoddy Dam question, definite and seemingly permanent settlement with Canada reached, Thompson, W. F., 24.
Peace, International Relations practical means of laying foundation for, Thompson, W. F., 28.
Pearl button industry in relation to gravid period of certain mussels, Van der Schalie, Henry, 406-410.
Perch (see also **Yellow pike-perch**), best weather for biting, Eschmeyer, R. W., 327-329.
in Lake Erie, agreement reached concerning uniform size limit, Thompson, W. F., 26.
Perry: see **Commodore Perry**.
Petromyzon marinus, spread through the Great Lakes, Hubbs, Carl L., and Pope, T. E. B., 172-176.
Philonema salvelini, new species of nematode parasitic on Salvelinus fontinals in Lake Edward, Quebec, Richardson, L. R., 352.
Phosphates and fixed nitrogen in newly impounded waters, Ellis, M. M., 66-68.
Phosphatids analysis of percentage in dry material for trout food tabulated, 294.
unoxidized, factor "H" in trout diet, Hewitt, Edward R., 291-297.
Phosphorus content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 112-113.
determination, method described by Juday et al. modified by Dean Taylor in experimental analyses, Surber, Thaddeus, and Olson, Theodore A., 107.
pH range of fluctuation in Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 108.
Pike, Esox lucius and E. vermiculatus, breeding and food habits, McNamara, Fred, 372-373.
northern, best weather conditions for biting, Eschmeyer, R. W., 327-329.
northern, yield in Chequamegon National Forest lakes, Elkins, Winston A., 311.
Pike-perch: see **Yellow pike-perch**.
Pike, walleyed, artificial propagaton, Butler, George E., 277-278.
walleyed, best weather for biting, Eschmeyer, R. W., 327-329.
Pilchard reduction into meal and oil on factory ships, Fieler, R. H., 438.
Pimelodus clarias: see **Catfish**.
Piscicola punctata parasitic on smallmouth black bass, black bullhead and green sunfish, Bangham, R. V., 357-358.
Plankton, method of measuring vertical and horizontal hauls in Michigan lakes, Miller, Donald E., 128-130.
occurred in Ohio lakes within one month after filling, Wickliff, E. L., and Roach, Lee S., 80.
Planting of fry of commercial species of fish should be made in waters from which the eggs were taken, Smith, Lester, 61.
Pollution from road dust and tar in England, Rushton, W., 387.
in slack water back of impounded dams, Ellis, M. M., 65.
of stream and lake, resolution regarding, 41-42.
report of Study Committee on, Denmead, Talbott, 29-31.
sugar beet waste, Adams, Milton P. (disc.), 389-390.
Ponds, in Minnesota, physical and chemical analyses; plankton study, Surber, Thaddeus, and Olson, Theodore A., 104-127.
Population density of brook trout in North Branch of Au Sable River, Michigan, statistics, Shetter, David S., 209.
Potassium and sodium content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 111.
Predators, damage caused by Golden-eyes and Merganser ducks in Michigan rearing ponds, Beach, U. Sidney, 338-341.
of smallmouth bass and their control, Kingsbury, Oliver R., 267-274, 1 fig.
of trout waters in Michigan, stomach analysis of American and Red-breasted Mergansers, Leonard, J. W., and Shetter David S., 335-337.

Preservation of fish aboard vessels while fishing at sea, new method adopted by menhaden industry, Fiedler, R. H., 37.
Presidents American Fisheries Society, terms of service and places of meeting, 6-7.
Productivity of Great Lakes on the decline, Van Oosten, John, 132.
of impounded waters, Ellis, M. M., (disc.), 72.
of Minnesota ponds (tables), 125-126.
through improved food conditions rather than greater volume of water, Wickliff, E. L., and Roach, Lee S., 77.
Progress in Biological Inquiries, Appendix III to Report of Commissioner of Fisheries quoted, 25.
Propagation, artificial versus natural, in Great Lakes, Van Oosten, John, 137-138.
of fish, artificial versus natural, Smith, Lester, 56-62.
Proteocephalus ambloplitis infection of bass in a rearing pond, Langlois, T. H., 364-365.
Proteocephalus fluviatilis parasitic on smallmouth black and rock bass, Bangham, R. V., 357-358.
Protozoa found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 119-124.
in newly impounded waters, Ellis, M. M., 66-68.
Pseudomonas fluorescens (?) causing air bladder infection of lake trout fingerlings, Wolf, Louis E., 359-363, 2 plates.
Pyloric appendages, vertebrae and gill rakers of salmon parr, tabulated, 222.
Races of fish in Great Lakes, or one homogeneous population to be determined through tagging, Van Oosten, John, 136-137.
Rainbow trout: see Trout, rainbow.
Rainy River pollution survey needed Thompson, W. F., 26.
Razor clam industry, Fiedler, R. H., 37.
Report of Committee on American Fish Policy available in mimeographed form, Wickliff, E. L., 29.
Reports of Commmittees published in Transactions: see Committee.
of Vice-Presidents of Divisions of Fish Culture, 32-33; Aquatic Biology and Physics, 34; Commercial Fishing, 34-37; Angling, 37-38.
Research, biological, some principles, Schultz, Leonard P., 188-192.
Reseach work in fisheries biology, grants-in-aid allotted by National Research Council, Hazzard, A. S., 34.
new technique to determine freshness of fish landed by fishermen developed by Bureau of Fisheries, Fiedler, R. H., 37.
training of skilled technicians desirable, Hubbs, Carl L., 54.
Resettlement Adminstration, M. E. C. W., Parks E. C. W., and U. S. Forest Service cooperating in survey of Michigan lakes, Miller, Donald E., 128-130.
Waterloo and Yankee Springs Projects, making fish catch records on Michigan lakes, Hazzard, A. S., and Eschmeyer, R. W., 88.
Resolution regarding International Cooperation and Action Upon Treaties and Conventions, 40-41.
regarding the late Henry O'Malley, 40.
Resolutions, report Committee on 1935-1936, 40-42.
Rhipidocotyle papillosum parasitic on smallmouth black bass, Bangham, R. V., 357-358.
Riffles aerate water and support forage fishes, crayfishes and insects and their flooding is to be avoided, Wickliff, E. L., and Roach, Lee S., 83.
Ring formation on scales of white cappie, Hansen, Donald F., 227-236, illus.
Robinson-Patman Act passed by 74th Congress, Fiedler, R. H., 35-36.
Roller dams, beneficial effect, Ellis, M. M., 66.
Rosefish and whiting from Atlantic Coast consumed in great quantities in mid-west, due to depletion of important species of fish in Great Lakes, Fiedler, R. H., 36.
increased catch in New England ports, Fiedler, R. H., 35.

Rotifera found in Minnesota ponds, tabulated, Surber, Thaddeus, and Olson, Theodore A., 123-124.
Sacandaga Reservoir, pike prouction unstable (disc.), 74.
Saginaw Bay production of yellow pike-perch, 1929-1935, tabulated, 148.
Saint Louis consumes quantities of Atlantic Coast fish, due to depletion of species from Great Lakes, Fiedler, R. H., 36.
Salmon (see also **Sockeye**), canning industry produced largest packs on record in 1936, Fiedler, R. H., 35.
fishermen cooperatives continue to function on Pacific Coast, Fiedler, R. H., 35.
parr, age, growth and characteristics, in West Coast rivers of Newfoundland, Belding, David L., 211-224.
tagging as a check on creel census, Huntsman, A. G., (disc.), 320; 321.
Salting fish operations on factory ships, Fiedler, R. H., 428-429.
Salvelinus fontinalis parasites, Richardson, L. R., 343-356, 11 fig.
Sampling errors in calculating the weight of fish in ponds, Mottley, C. McC., 422-426.
San Francisco Bay area, study of the marketing of fish conducted by the U. S. Bureau of Fisheries, Fiedler, R. H., 37.
Sanson, William J., deceased, 48.
Sardine depletion, resolution regarding, 41.
factory ship operations, proposed legislation affecting not passed, Fiedler, R. H., 36.
fishery, provision for biological study of, in California, proposed legislation not passed, Fiedler, R. H., 36.
reduction into meal and oil on factory ships, Fiedler, R. H., 438.
Sardines and crabs, cooperative societies for sale of, formed in California, Fiedler, R. H., 35.
Scales of white crappie, date of annual ring formation, Hansen, Donald F., 227-236, Illus.
Scenedesmus in digestive tract of Daphnia pulex, Smith, M. W., 288.
Sculpins (Cottidae) in Central New York, stomach analyses, Koster, Wm. J., 374-382.
Sea fishes supplied to people of mid-west due to depletion of important species of Great Lakes, Fiedler, R. H., 36.
mussel industry on Atlantic Coast, Fiedler, R. H., 37.
Seal treaties outstandingly successful, Thompson, W. F., 27.
Selenastrum as food for Daphnia pulex, Smith, M. W., 288-289.
Sex ratio in Atlantic salmon parr, Belding, David L., 223, and disc., 224.
Shad, gizzard, recommended for stocking in newly impounded waters, Wickliff, E. L., and Roach, Lee S., 80.
Sheldrakes: see **Ducks, Merganser.**
Shelter for fish (disc.), 72; 74.
in above-dam stream bottoms of sand, pebbles or small gravel obtained with large flat stones, Wickliff, E. L., and Roach, Leo S., 84.
Shiner: see **Golden shiner.**
Ship Subsidy Act passed by 74th Congress, Fiedler, R. H., 36.
Shipping bills affecting fishing vessels not passed, Fiedler, R. H., 36.
Shrimp tagging, Higgins, Elmer (disc.), 276.
Sigurdson, Sam, finds water hardening process in hatching walleyed pike eggs unessential, Butler, George E., 277.
Silica content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 112.
Silt, effects of silting over of stream and lake bottoms to be corrected and prevented by future fish management, Hubbs, Carl L., 54.
from erosion and organic detritus in impounded waters detrimental to fish, Ellis, M. M., 64-66.
Silver hake, increased sale, Fiedler, R. H., 35.
Simulium larvae as food for Cottus bairdii and C. cognatus, Koster, Wm. J., 375.

Smelt dispersal in the Great Lakes region, Van Oosten, John, 160-170.
in Green Bay (Lake Michigan), biological and economic importance, Schneberger, Edward, 139-142.
introduced into Great Lakes, should the species be exterminated or protected? Van Oosten, John, 138.
Social Security Act passed by 74th Congress, Fiedler, R. H., 36.
Sockeye salmon, superiority of gravel-hatched eggs, Robertson, Alexander, 279-282.
treaty with Canada signed and ratified, Thompson, W. F., 25.
Sodium and potassium content of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 111.
Sole drag net fishery on Pacific Coast steadily growing, Thompson, W. F., 27.
Spawn-fishing for lake trout, whitefish and yellow pike-perch, size of gill-net mesh, Smith, Lester, 60-61.
Spawning habits in Brazilian waters, Ihering, Rodolpho Von (disc.), 75.
habits of Esox lucius, McNamara, Fred, 372-373.
of golden shiners retarded (disc.), Cooper, Gerald P., 265; Kingsbury, O. R., 266.
Spearing catches compared with line fishing (table), 89.
Speckled trout: see **Trout, speckled.**
Sphingomyelin in insect bodies and consumed by trout, Hewitt, Edward R., 292.
Sport fishing in Maryland, importance, Truitt, R. V., and Vladykov, V. D., 403-405.
Standards accepted universally found erroneous for Great Lakes statistics, Van Oosten, John, 135.
State and Federal Agencies, resolution regarding cooperation, 41.
and government cooperation results in fish increase, Earle, Swepson, 392-394.
Statistical standards for Great Lakes fisheries extremely complex, Van Oosten, John, 135.
Statistics, cooperation of state fishery agencies urged, Fiedler, R. H., 36.
sampling errors in calculating the weight of fish in ponds, Mottley, C. McC., 422-426.
Stizostedion vitreum, increased abundance in relation to artificial propagation in lakes Huron and Michigan, Hile, Ralph, 143-159.
Stream and lake improvement in National Parks should not include introduction of exotic species, Hubbs, Carl L., 53.
and lake pollution, resolution regarding, 41-42.
fish (16 species) of Wayne County (Ohio) parasitized by flukes, cestodes, nematodes, Acanthocephala and leeches, Bangham, R. V., 357-358.
improvement in Michigan, effectiveness and permanency of devices and evaluation of biological changes produced, Tarzwell, Clarence M., 177-187.
Striped bass: see **Bass, striped.**
Sulphates and sulphides, insoluble, in Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 111-112.
Summer fishing vs. winter fishing in Michigan lakes, Hazzard, A. S., and Eschmeyer, R. W., 87-97, map.
Sunfish, best weather for biting, Eschmeyer, R. W., 327-329.
Surveying Michigan lakes, Miller, Donald E., 128-130.
Swordfish, frozen, import duty raised fifty per cent, Fiedler, R. H., 36.
Tagging black bass, variation in method devised, Shetter, David S. (disc.), 319.
native stream fish, Bangham, R. V., 316-318.
of crayfish (disc.), 276.
test showed metal tag on the opercle of halibut to be more reliable than tatooing or belly tagging which often killed the fish, Thompson, W. F. (disc.), 322.
Tags coated with algae and lime (disc.), 322.
Tapeworm infection of bass in rearing pond, Langlois, T. H., 364-365.
Tattooing vs. tagging fish (disc.), 320.
Taylor, Dean, modifies method of phosphorus determination described by Juday et al., Surber, Thaddeus, and Olson, Theodore A., 107.
Temperature influence on under-ice migration of fish, Aitken, W. W., 98-103, map.

Tennessee Valley Authority, suggestion that trout waters be made below the north dam by releasing cold bottom water in steady current during warmer months, Hubbs, Carl L. (disc.), 71.
Tennessee Valley, fisheries program, Cahn, Alvin R., 398-401.
Text book on fish culture desirable, Bost, J. E., 298.
Thompson, Eben P., deceased, 48.
Thyroid disease of trout, Rushton, W., 385.
Time and Place, report committee on, 1935-1936, 43.
Toronto, Ontario, conference of Prov. of Ontario, State of Michigan and U. S. Bureau of Fisheries held March 16-17, 1936, Thompson, W. F., 26.
Training of aquatic biologists recommended, Hazzard, A. S., 34.
of men in practical fisheries problems encouraged through presentation of limnological equipment to Ohio University and Akron Unversity, Wickliff, E. L., and Roach, Lee S., 85.
through provision of fellowships and student assistantships recommended, Hubbs, Carl L., 54-55.
Transactions American Fisheries Society, copies available for scale, 1892-1935, 22.
Trautman, M. B., made survey of Ohio waters, Wickliff, E. L., and Roach, Lee S., 78-80.
Treasurer's report, 1935-1936, Gordon, Seth, 18-21.
Treaties and conventions, resolution regarding, 40-41.
Treaties, seal and halibut outstandingly successful, Thompson, W. F., 27.
Treaty proposed for regulation of Lake Erie fisheries, Thompson, W. F., 26.
with Canada for rehabilitation of the sockeye run in Fraser River, Thompson, W. F., 24-25.
Trees and brush, in impounded waters, relative value, Ellis, M. M. (disc.), 72.
Trent Valley canal system, Ontario, vegetation as influence on maskinonge production, Harkness, W. J. K. (disc.), 74-75.
Trichoptera a food item of Cottus bairdii and C. cognatus, Koster, Wm. J., 374-379.
as food for young largemouth bass, tabulated, 253-259.
Triganodistomum simeri parasitic on common sucker and hog sucker, Bangham, R. V., 357-358.
Trout, blood clots in the gills and recommended treatment, Wolf, Louis E., 369-371, 1 fig.
brook, migration, growth rate and population density in N. Branch of Au Sable River, Michigan, Shetter, David S., 203-210.
"buckskin" and ciscowet, life-history studies desirable, Smith, Lester, 61.
fingerlings, air bladder infection, Wolf, Louis E., 359-363, 2 plates.
hybridization of cutthroat and rainbow, Hubbs, Carl L. (disc.), 397.
lake, size of gill-net mesh in spawn fishing, Smith, Lester, 60-61.
rainbow, and bottom fauna production in one mile of stream, Surber, Eugene W., 193-202, 1 fig.
rarely consumed by Cottus spp. and competition for food restricted to bottom level of streams, Koster, Wm. J., 379-380.
speckled, of Lake Edward, observations on parasites, Richardson, L. R., 343-356, 11 fig.
stream improvement in Michigan, experimental evidence, Tarzwell, Clarence M., 177-187.
waters below north dam of T. V. A. possible through steady release of cold bottom water during warmer months, Hubbs, Carl L. (disc.), 71.
Tuna fisheries extension southwards from California ports suggest formation of international Fisheries Commission with Mexico, Thompson, W. F., 27.
more canned in California in 1935 than in any prevous year, Fiedler, R. H., 35.
Turbidity range of Minnesota ponds, Surber, Thaddeus, and Olson, Theodore A., 108-109.
T. V. A.: see **Tennessee Valley Authority.**
U. S. Bureau of Fisheries aided advertising campaigns by supplying information as to food value of fish and shellfish, Fiedler, R. H., 36.

Columbia (Missouri) Unit, Ellis, M. M., 64.
in cooperation with the Biological Readjustment Unit, hatchery constructed for stocking Norris Reservoir, Cahn, Alvin R., 399.
Province of Ontario and State of Michigan conference held at Toronto, March 16-17, 1936, Thompson, W. F., 26.
publishes booklets on practical fish cookery and oysters, Fiedler, R. H., 36.
sponsored a study of the marketing of fish in the San Francisco Bay area and an economic study of the halibut fishery industry, Fiedler, R. H., 37.
U. S. Department of Agriculture and Department of Forestry, cooperation in restoration of productive conditions of artificial and natural lakes, Markus, Henry C. (disc.), 73.
U. S. Forest Service, Resettlement Administration, M. E. C. W. and Parks E. C. W. cooperating in survey of Michigan lakes, Miller, Donald E., 128-130.
Vegetation, aquatic, (should be of type adapted to water in which it is planted, Wickliff, E. L., and Roach, Lee S., 81.
control in hatcheries, Kingsbury, Oliver R., 272.
in impounded waters, Ellis, M. M., 66-68.
Vertebra count in distinguishing salmon of various rivers, Belding, David L., 221.
Visitors attending 66th Annual Meeting at Grand Rapids, Michigan, 1936, 16-17.
Vitamins A and D found 100 times more potent in swordfish liver oil than in cod liver oil, Fiedler, R. H., 37.
Walleyed pike: see **Pike**, walleyed.
Warner-Bower fish conveyor for surmounting dams, Bower, E. A., 411-414, 2 fig.
Washington, D. C., meetings of Lake Erie Advisory Committee, Thompson, W. F., 26.
Washington State oyster producers considering formation of cooperative society for outlet of their product, Fiedler, R. H., 35.
Water-tiger: see **Dytiscus**.
Wayne-County, Ohio, stream fish parasitized by flukes, cestodes, nematodes, Acanthocephala and leeches, Bangham, R. V., 357-358.
Weather conditions as affecting catch for various fish tabulated, 328.
Weight of fish in ponds, sampling errors, Mottley, C. McC., 422-426.
Westerman, Fred A., appreciative mention, Van Oosten, John 160.
Whale reduction into meal and oil on factory ships, Fiedler, R. H., 433-438.
Whaling Convention, act effect to, passed by 74th Congress, Fiedler, R. H., 36.
Multilateral Conventon of Geneva, 1931, ratified by act of 74th Congress and approved by President, May 1, 1936, Thompson, W. F., 24.
Wheeler Lake: see **Lake, Wheeler**.
Whistlers:: see **Ducks, golden-eyes**.
White crappie, date of annual ring formation, Hansen, Donald F., 227-236, illus.
Whitefish, size of gill-net mesh in spawn-fishing, Smith, Lester, 60-61.
White, Thomas, Conservation Officer, fishing record on Houghton Lake, Michigan, Hazzard, A. S., and Eschmeyer, R. W., 92.
Whiting and rosefish from Atlantic Coast consumed in large quantities in mid-west, due to depletion of important species of fish in Great Lakes, Fiedler, R. H., 36.
increased catch in New England ports, Fiedler, R. H., 35.
Merluccius bilinearis, composition and utilization, Bean, D. A., Clague, J. A., and Fellers, C. R., 415-421.
Wildlife International Conference: see **American Wildlife Institute**, international conference.
Wildlife technicians, North Central States Conference organized to facilitate and coordinate research in fish and game, Hazzard, A. S., 34.
Winter conditions in open water and shallow areas improved through cutting ice and formation of channels, Wickliff, E. L., and Roach, Lee S., 82.
fishing vs. summer fishing in Michigan lakes, Hazzard, A. S., and Eschmeyer, R. W., 87-97, map.

under-ice migration of fish, Aitken, W. W., 98-103, map.
Wisconsin lakes (Chequamegon National Forest), fish yield study, Elkins, Winston, A., 306-312.
Wolf Creek, Ohio, comparative oxygen, bottom organisms and Zooplankton data in impounded water and natural stream low dams (table), 83.
Yellow pike-perch, increased abundance in relation to artificial propagation in lakes Huron and Michigan, Hile, Ralph, 143-159.
pike-perch, size of gill-net mesh in spawn-fishing, Smith, Lester, 60-61.

PART 11. AUTHOR INDEX

Adams, Milton P.: Problem of beet sugar waste pollution (disc.), 389-390.
Aitken, W. W.: Fish movement under the ice in an Iowa lake, 98-103, map.
Bangham, R. V.: Parasites of Wayne County (Ohio) stream fish, 357-358.
Tagging native stream fish, 316-318.
Beach, U. Sidney: Destruction of trout by fish ducks, 338-341.
Bean, D. A., Clague, J. A., and Fellers, C. R.: Composition and utilization of the Atlantic whiting, 415-421.
Belding, David L.: Altantic salmon parr of the West Coast rivers of Newfoundland, 211-224.
Bost, J. E.: Text book on fish culture desirable, 298.
Bower, E. A.: The Warner-Bower fish conveyor, 411-414, 2 fig.
Butler, George E.: Artificial propagation of walleyed pike, 277-278.
Cahn, Alvin R.: Fisheries program in the Tennessee Valley, 398-401.
Clague, J. A., joint author: see Bean, D. A., —, and Fellers, C. R.
Cobb, Eben W.: Report of the Librarian for 1936, 21-22.
Cooper, Gerald P.: Food habits, growth rate and cannibalism of young Aplites salmoides, 242-265, 4 fig.
Croker, Richard S.: How California is measuring the angler's catch, 301-305.
Davis, H. S.: Furunculosis possibly introduced into Europe from America (disc.), 389.
Denmead, Talbott: Report of Pollution Study Committee, 29-31.
Earle, Swepson: Fish increase responds to government and state cooperation, 392-394.
Elkins, Winston A.: Fish yield study for certain lakes in the Chequamegon National Forest, 306-312.
Ellis, M. M.: Some fishery problems in impounded waters, 63-70.
Eschmeyer, R. W.: Creel census on Fife Lake, 324-334.
Eschmeyer, R. W.: joint author: see Hazzard, A. S.
Fellers, C. R., joint author: see Bean, D. A.; Clague, J. A. and—
Fiedler, R. H.: Report Division of Commercial Fishing, 1935-1936, 34-37.
The factory ship, its significance in trade and commerce, 427-440.
Gordon, Seth: Minutes of meeting of Executive Committee, 23.
Report of the Secretary-Treasurer for 1935-1936, 18-21.
Hachey, H. B.: Submarine physiography and oceanographical problems of the Scotian shelf, 237-241, map.
Hansen, Donald F.: Date of annual ring formation in scales of white crappie, 227-236.
Harkness, W. J. K.: Vegetation influencing maskinonge production in Trent Valley canal system, Ontario (disc.), 74-75.
Hazzard, A. S.: Report Division of Aquatic Biology and Physics, 34.
Hazzard, A. S., and Eschmeyer, R. W.: A comparison of summer and winter fishing in Michigan lakes, 87-97, map.
Hewitt, Edward R.: Identification of factor "H" in the nutrition of trout, 291-297.
Introduction of French crayfish desirable (disc.), 276.
Higgins, Elmer: Tagging of shrimp and herring (disc.), 276.
Hile, Ralph: Stizostedion vitreum increase in relation to artificial propagation in lakes Huron and Michigan, 143-159.
Hubbs, Carl L.: Committee on Common and Scientific Names of Fishes, report to be completed, 28.
Fish management: looking forward, 51-55.
Hubbs, Carl L., and Pope, T. E. B.: The spread of the sea lamprey through the Great Lakes, 172-176.
Huntsman, A. G.: Creel census of salmon proved only 25% accurate by tagging experiments, 320-321.

Smelt an asset for winter fishing (disc.), 171.
Ihering, Rodolpho von: Impounded water problems peculiar to Brazil (disc.), 75.
Kingsbury, Oliver R.: Foes encountered in rearing of smallmouth bass, 267-274, 1 fig.
Spawning of golden shiners retarded (disc.), 266.
Koster, Wm. J.: The food of sculpins (Cottidae) in Central New York, 374-382.
Langlois, T. H.: Bass tapeworm infection in a rearing pond, 364-365.
Habits of the crayfish, Cambarus rusticus Girard, 275-276.
Report of the Division of Fish Culture, 1935-1936, 32-33.
Leonard, J. W., and **Shetter,** David S.: Studies on merganser depredations in Michigan trout waters, 335-337.
Lincoln, Guy: Furunculosis checked through feeding Hewitt's trout food (disc.), 390.
Lack of adequate text book on fish culture (disc.), 300.
Locke, S. B.: Report Division of Angling, 1935-1936, 37-38.
Madsen, David H.: Protection of native fishes in the National Parks, 395-397.
Markus, Henry C.: Restoration of productive conditions in lakes through cooperation of U. S. Department of Agriculture desirable (disc.), 73.
McNamara, Fred: Breeding and food habits of Esox lucius and E. vermiculatus, 372-373.
Miller, Donald E.: Michigan lake survey—a comparative enterprise, 128-130.
Mottley, C. McC.: Sampling errors in calculating the weight of fish in ponds, 422-426.
Olson, Theodore A., joint author: see **Surber,** Thaddeus.
Pope, T. E. B., joint author: see **Hubbs,** Carl L.
Reid, Kenneth A.: Reduction of kill in angling as proposed by S. B. Locke, commended, 38.
Richardson, L. R.: Speckled trout parasites, 343-356, 11 fig.
Rivero, Luis Howell: The introduced largemouth bass a predator on native Cuban fishes, 367-368.
Robertson, Alexander: Hatching fry in gravel, 279-282.
Rushton, W.: Fish hatchery work in North America (letter), 390-391.
Fresh water fishery problems of the British Isles, 383-389.
Good fishing in impounded waters practically non-existent in England (disc.), 85-86.
Roach, Lee S., joint author: see **Wickliff,** E. L.
Savage, James: Effect of gravel in raceways, 283-286.
Schalie: see **Van der Schalie.**
Schneberger, Edward: The biological and economic importance of the smelt in Green Bay, 139-142.
Schultz, Leonard P.: Lampreys as bait and food for fish (disc.), 176.
Principles of biological fisheries research, 188-192.
Shetter, David S.: Jaw-tagging of black bass, improved method devised (disc.), 319.
Migration, growth rate and population density of brook trout in N. branch of Au Sable River, Michigan, 203-210.
Shetter, David S., joint author: see **Leonard,** J. W.
Smith, Lester: Observations on natural versus artificial propagation of commercial species of fish in the Great Lakes Region, 56-62.
Smith, M. W.: Food of Daphnia pulex in fertilized water, 287-290.
Smith, Osgood R.: Creel census from Dry River New Hampshire, 313-315.
Surber, Eugene W.: Rainbow trout and bottom fauna production in one mile of stream, 193-202, 1 fig.
Surber, Thaddeus, and **Olson,** Theodore A.: Some observations, on Minnesota fish ponds, 104-127.
Tarzwell, Clarence M.: Trout stream improvement in Michigan, experimental evidence, 177-187.

Thompson, W. F.: Belly tagging of halibut often killed the fish; metal tag on opercle found superior to tatooing method (disc.), 322.
Report of the Committee on Foreign Relations for 1935-1936, 24-27.
Truitt, R. V., and Vladykov, V. D.: Importance of sport fishing in Maryland, 403-405.
Striped bass investigations in Chesapeake Bay, 225-226.
Van der Schalie, Henry: Gravid period of certain muscles in relaton to the pearl button industry, 406-410.
Van Oosten, John: The dispersal of smelt, Osmerus mordax, in the Great Lakes region, 160-170.
The Great Lakes fisheries: their proper management for sustained yields, 131-138.
Vladykov, V. D.: Tagging experiments n fresh and salt water (disc.), 322.
Vladykov, V. D., joint author: see **Truitt, R. V.**
Von Ihering: see **Ihering, Rodolpho von.**
Wickliff, E. L.: Report of Committee on American Fish Policy, 29.
Wickliff, E. L., and Roach, Lee S.: Some studies of impounded waters in Ohio, 76-85, 3 fig.
Wolf, Louis E.: Air bladder disease in lake trout fingerlings, 359-363, 2 plates.
Blood clots in the gills of trout, 369-371, 1 fig.